This TECHNICAL SEMINAR

IS INTENDED FOR PLANT PERSONELLS WHO WANT TO GAIN AN UNDERSTANDING OF THE BASICS OF INDUSTRIAL COMPRESSED AIR SYSTEM

NORGREN

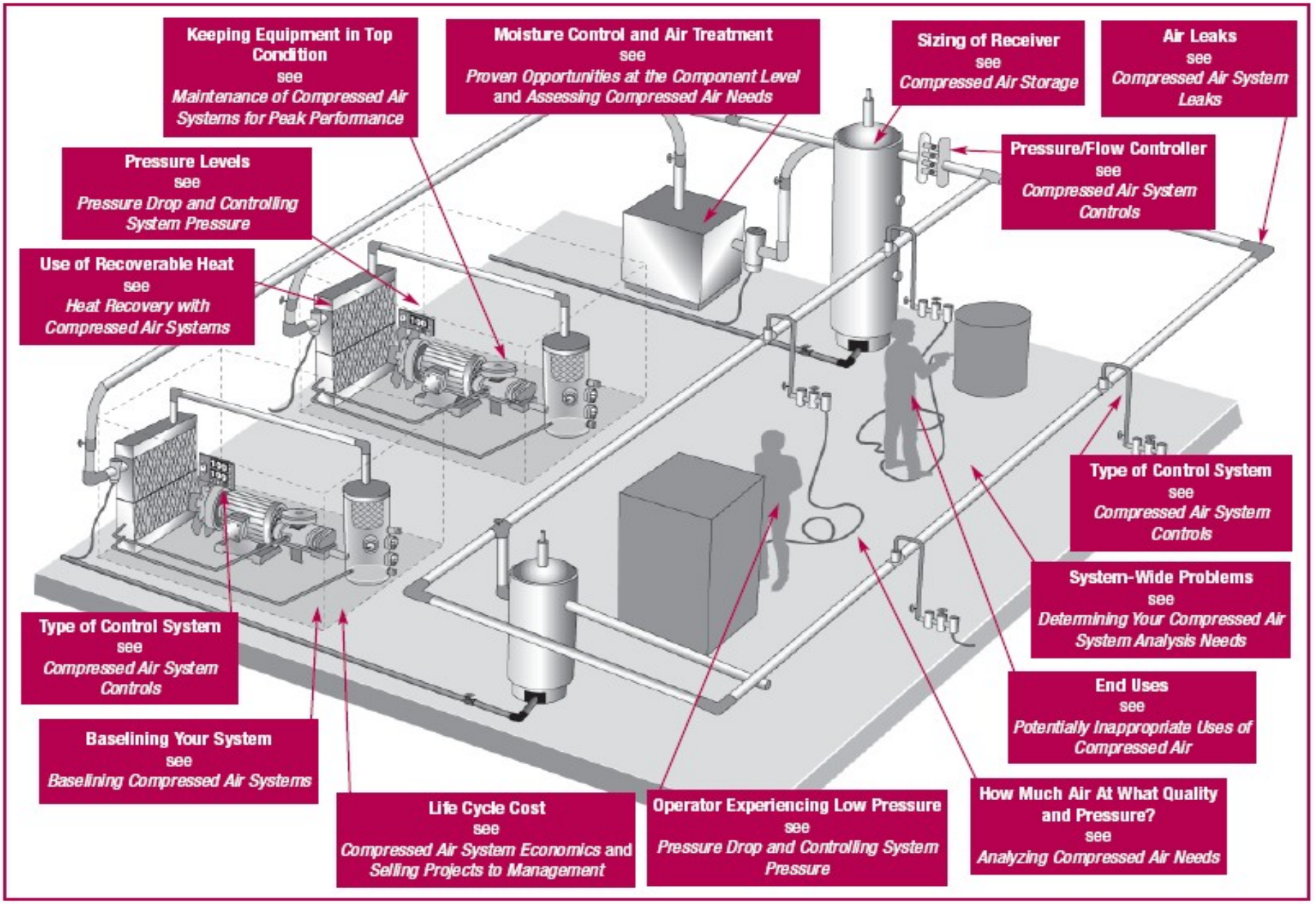
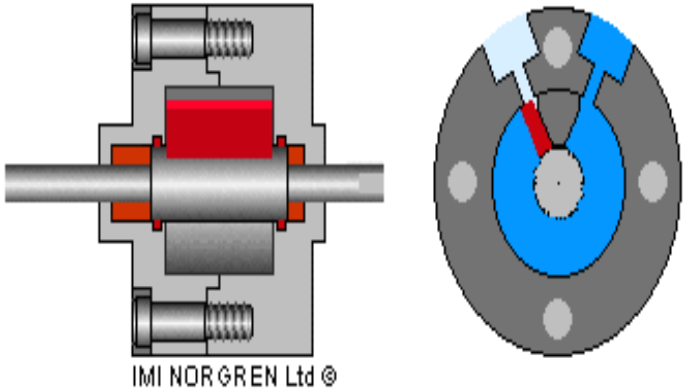


Figure 2.1 Performance Opportunities.

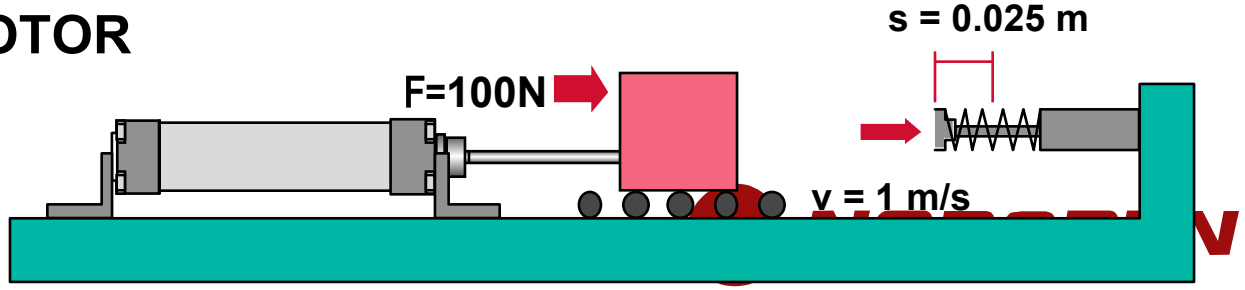
INPUT POWER FOR A *FLUID SYSTEM*

is **ALWAYS electrical (electric motor) or mechanical (from an engine)**



THE POWER IS THEN CONVERTED TO EQUIVALENT AMOUNT of *FLUID POWER* by means of an AIR COMPRESSOR or HYDRAULIC POWER PACK

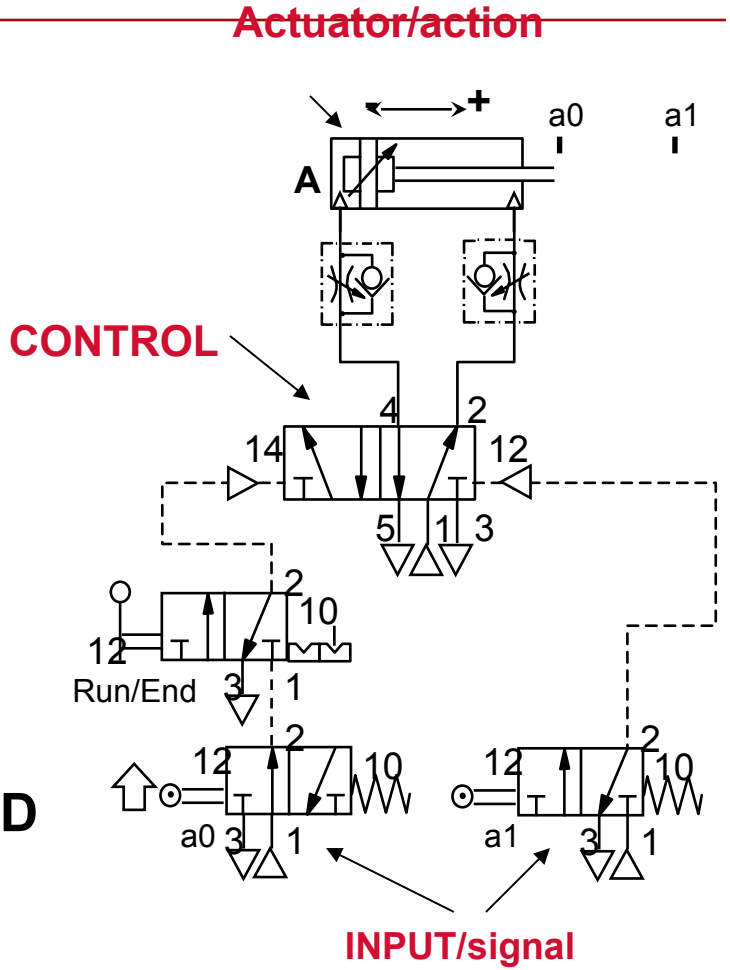
IT CAN BE TRANSMITTED THRU moderate distance and then be converted back to MECHANICAL POWER by means of A LINEAR MOVING PISTON or a ROTATING FLUID MOTOR



DURING IT'S TRANSITION suitable *VALVING(valves)* is added *CONTROL* direction of FLOW

TO *REGULATE the rate of* FLOW and to limit the maximum *PRESSURE* in the PISTON and transmitting PIPES or tubings

THE WHOLE ARRANGEMENT IS CALLED THE *"FLUID POWER CIRCUIT"*



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COMPRESSED AIR SYSTEM

Consist of a SUPPLY SIDE, which includes COMPRESSORS and AIR TREATMENT

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COMPRESSED AIR SYSTEM

And a DEMAND SIDE, which includes DISTRIBUTION and STORAGE systems, and END-USE equipment

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A properly managed SUPPLY SIDE

Will result in CLEAN, DRY, STABLE air being DELIVERED at the proper PRESSURE in a dependable COST EFFECTIVE manner

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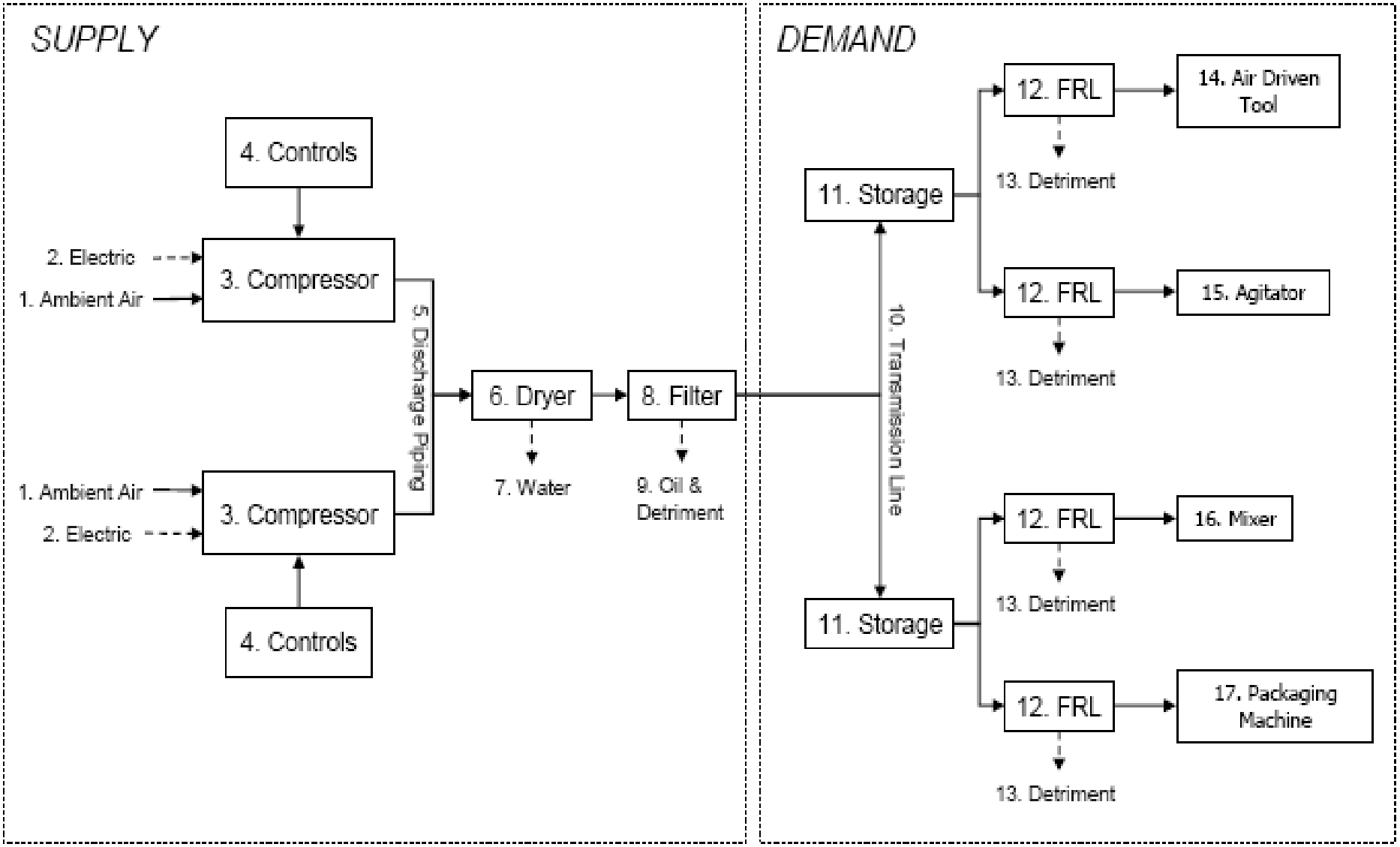

Figure C.1 – Compressed air system layout

IMPROVING and MAINTAINING peak

COMPRESSED AIR performance requires addressing both the SUPPLY SIDE and DEMAND SIDE and how they INTERACT

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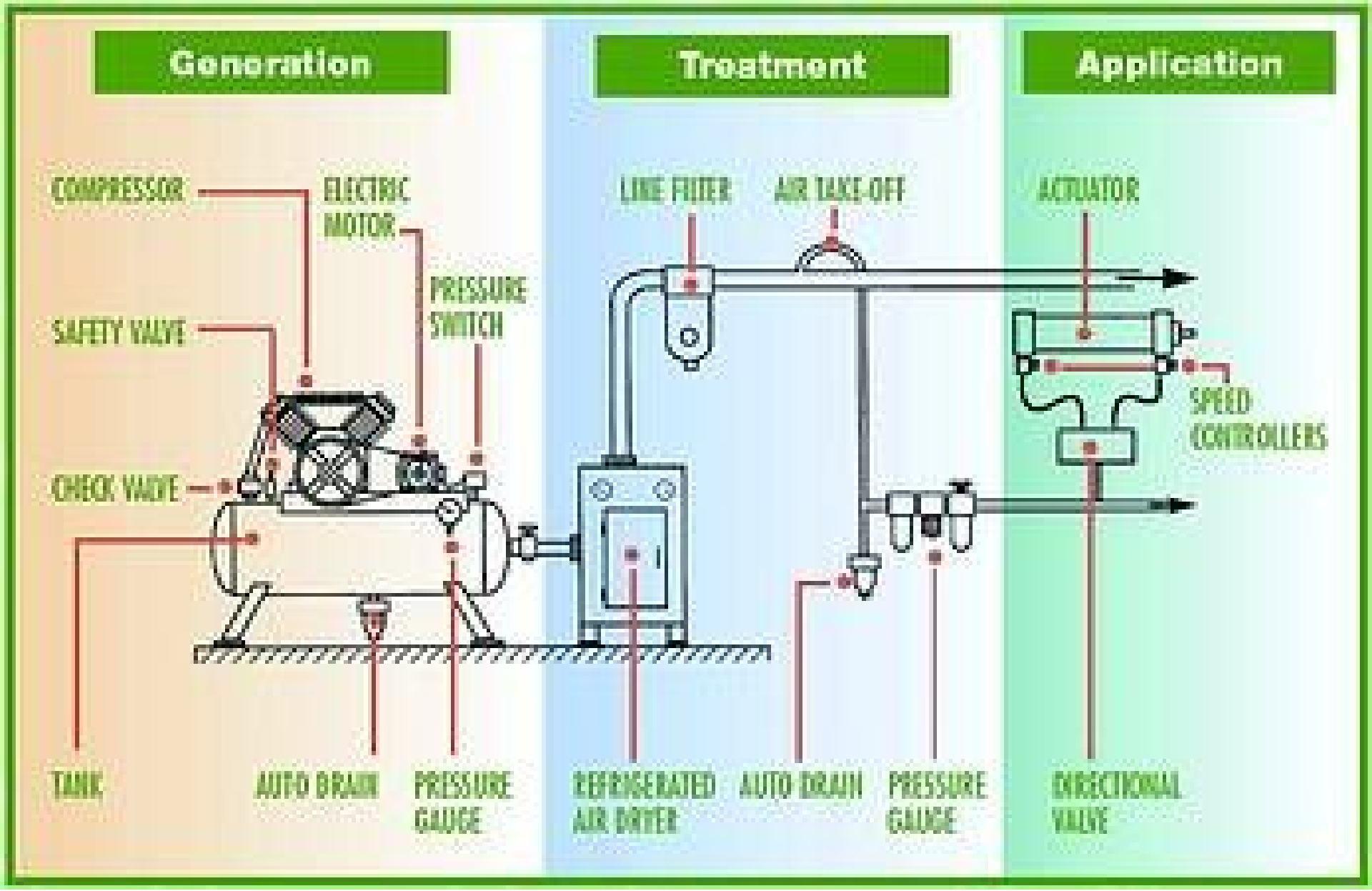
Generation
Treatment
Application
COMPRESSOR
ELECTRIC MOTOR
PRESSURE SWITCH
SAFETY VALVE
CHECK VALVE
TANK
AUTO DRAIN
PRESSURE GAUGE
REFRIGERATED AIR DRYER
LINE FILTER
AIR TAKE-OFF
AUTO DRAIN
PRESSURE GAUGE
ACTUATOR
SPEED CONTROLLERS
DIRECTIONAL VALVE

WHAT TO EXPECT AFTER THE PRESENTATION

To understand better COMPRESSED AIR FACILITY configuration and management

To know how to specify CORRECT PIPE sizing relative to type of compressor

To be able to assign appropriate TANK OR RECEIVER size in relation to your compressed air plant

To be able to calculate amount of moisture in a given compressed air system

To be able to know and size the various components needed in COMPRESSED AIR TREATMENT

To introduce participants to the advantages of the FREE TRAINING MATERIALS we are also going to provide for “follow on thru” learning and eventually establish their own in-house training

COMPRESSED AIR SYSTEM

Consist of a SUPPLY SIDE, which includes COMPRESSOR and AIR TREATMENT

And a DEMAND SIDE, which includes DISTRIBUTION and STORAGE systems and END-USE equipment

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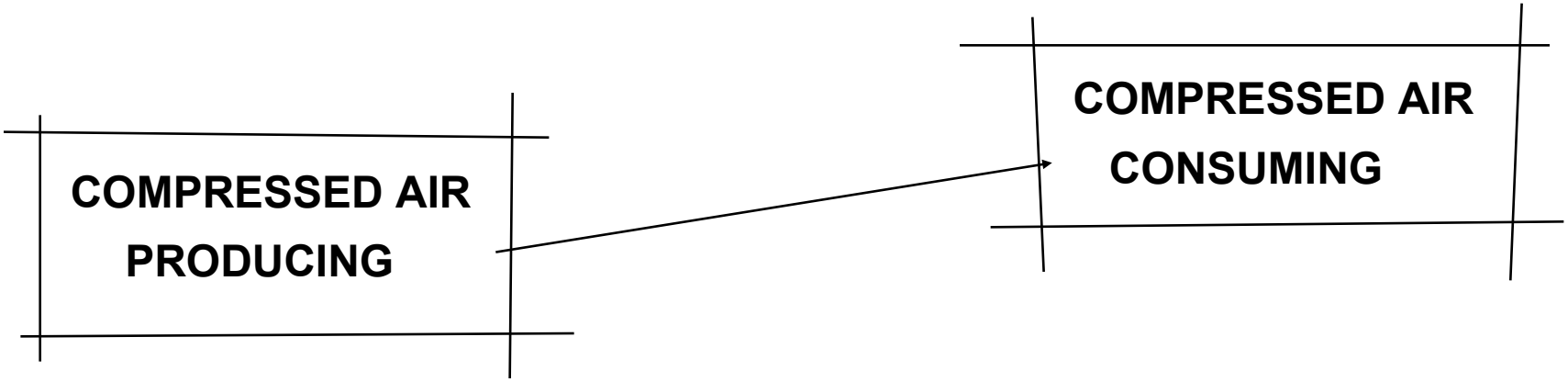
YOUR COMPRESSED AIR FACILITY



A properly managed SUPPLY SIDE

Will result in CLEAN, DRY, STABLE air being DELIVERED at the proper PRESSURE in a dependable COST EFFECTIVE manner

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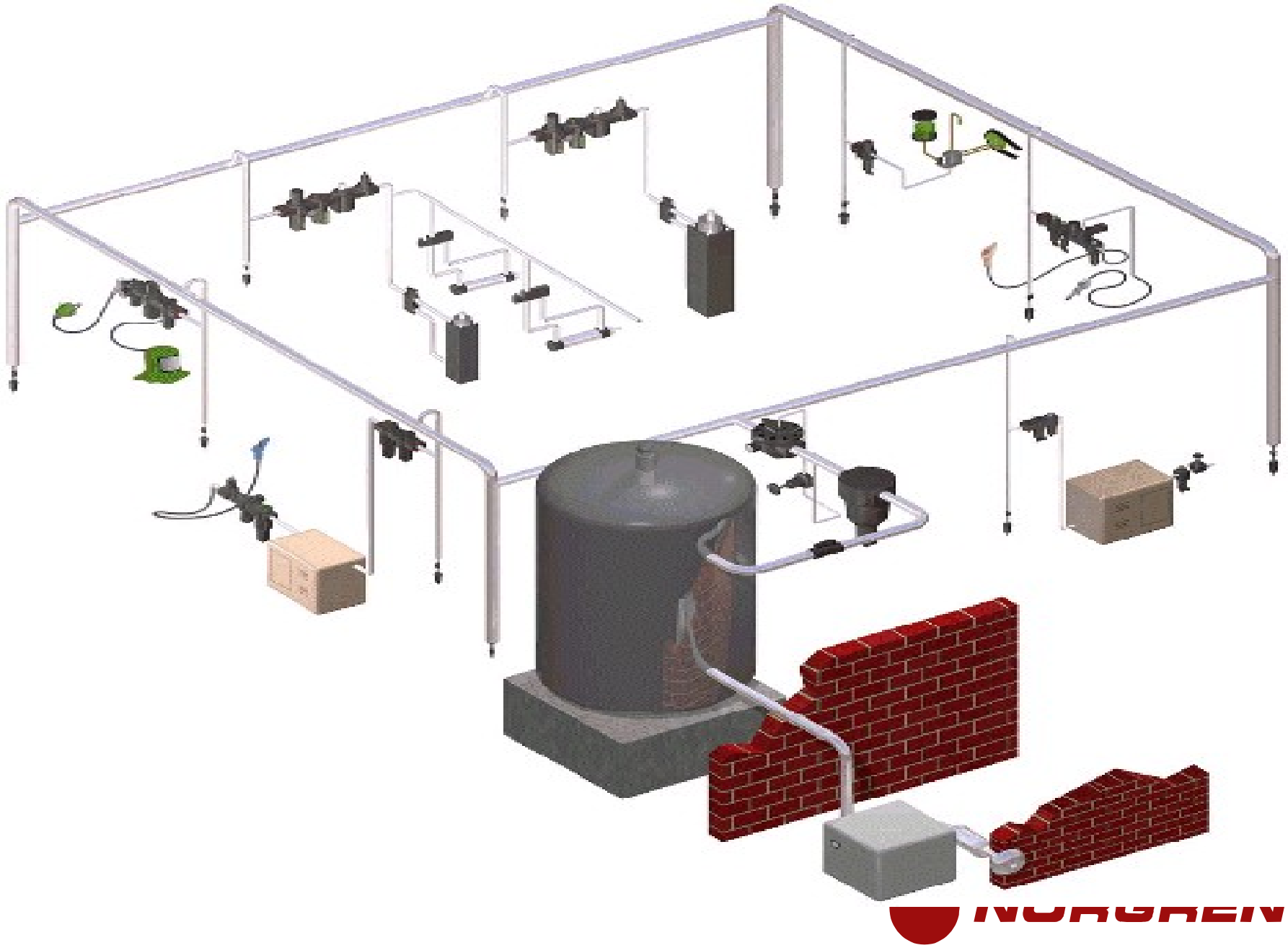
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Improving and maintaining peak air performance

Requires addressing both the SUPPLY SIDE and the DEMAND SIDE and how they interact

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COMPONENTS of an INDUSTRIAL COMPRESSED AIR SYSTEM

A COMPRESSOR IS MACHINE THAT INCREASES PRESSURE BY REDUCING A SPECIFIC CHAMBER VOLUME

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Reciprocating compressors were the first of the modern air *air compressor designs*. Reciprocating compressors utilize a piston moving within a cylinder to compress low-pressure air to high pressure. They are available in single-acting and double-acting configurations. Each of these configurations utilizes a variety of cylinder layouts.

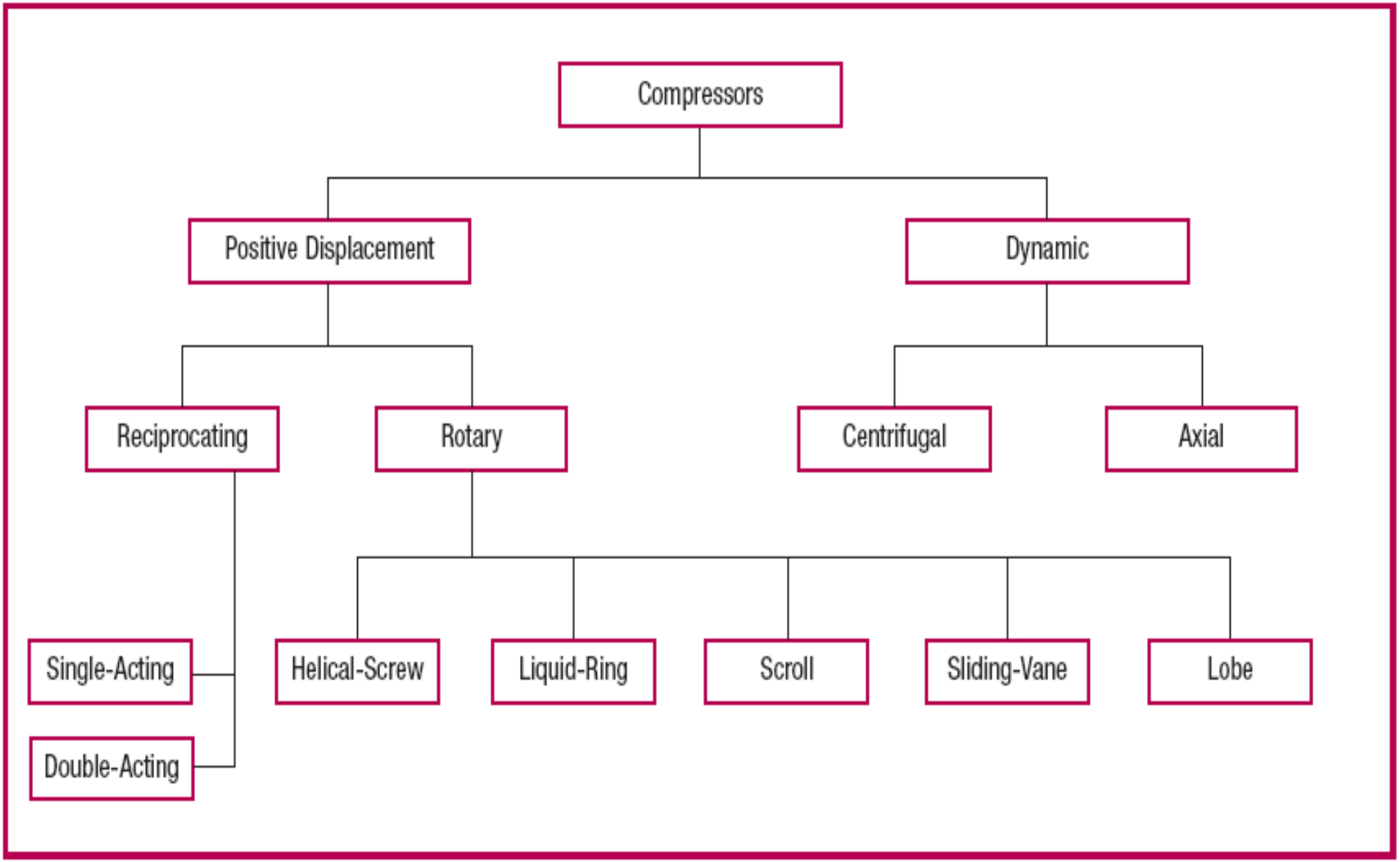


Figure 1.2 Compressor Family Tree.

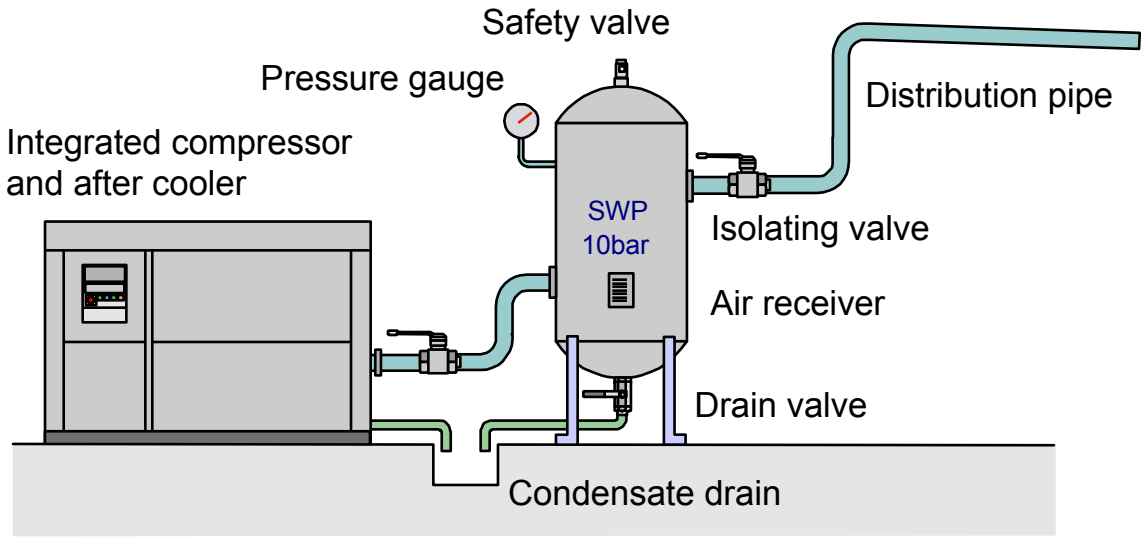
The compressor

Compressed air can be produced via two processes :
***Dynamic compression (conversion of the air velocity into pressure) :**
radial and axial compressors.

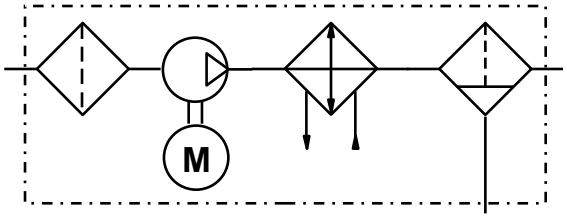
***Displacement compression (reduction of the air volume) :**
reciprocating compressors (piston type) and rotary compressors (screw- , vane-, roots- or liquid ring compressors).

Compressor installation

- Typical medium size compressor installation
- Integrated compressor unit including inlet filter, electrically driven compressor, after cooler and water separator
- Air receiver to smooth demand surges, and provide additional cooling and water collection



Symbol for contents of the Integrated compressor



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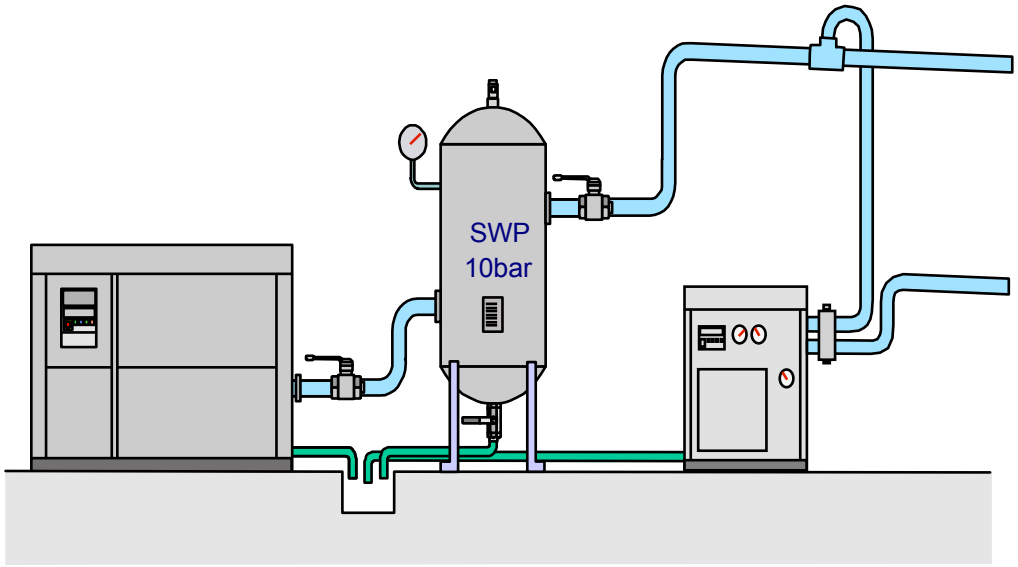
Compressor, receiver, dryer



- Suction side
- Inlet filter
- Compressor
- After cooler
- Moisture trap
- Auto drain
- Shut off valve
- Receiver w/ Auto drain
- Shut off valve
- Bypass option
- Mechanical main line filter
- Compressed air dryer
- Coalescing main line filter

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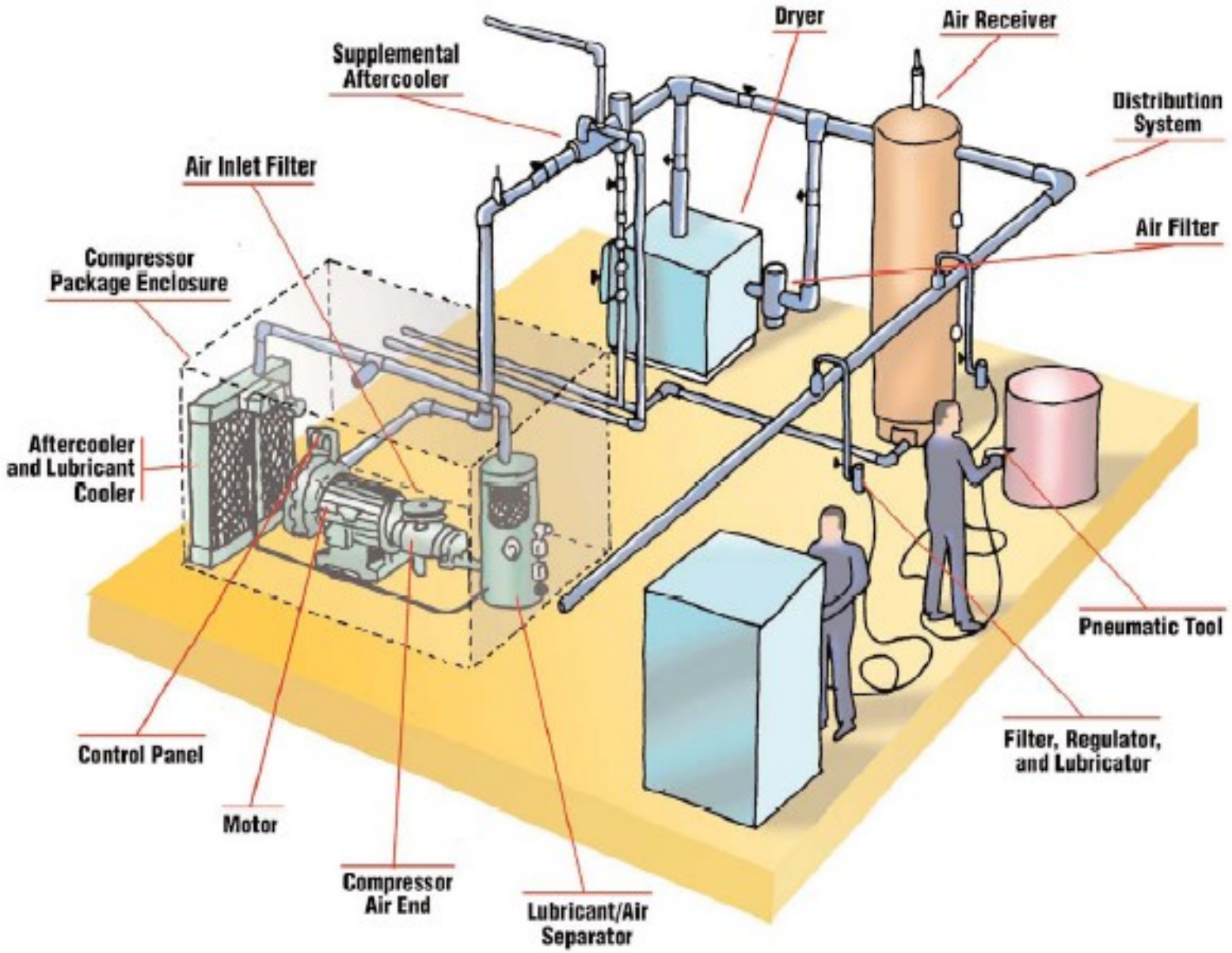
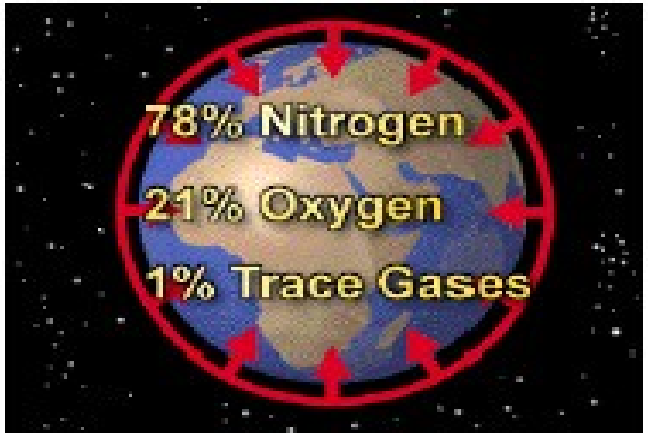
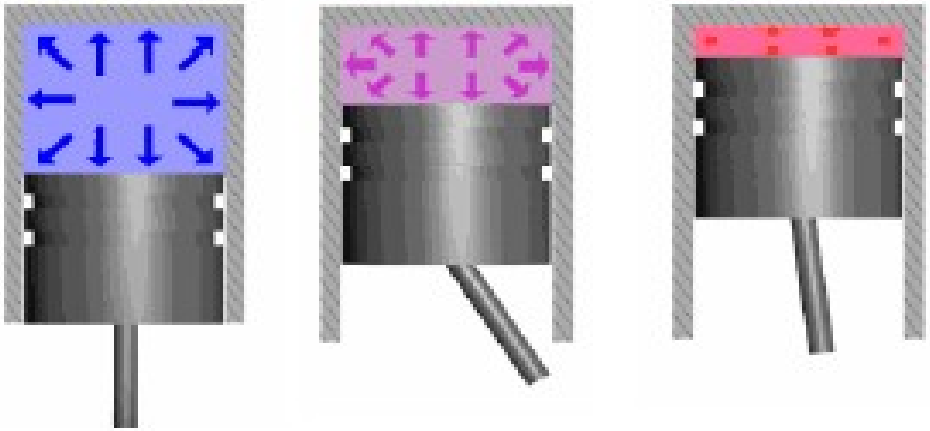

Dryer
Air Receiver
Supplemental Aftercooler
Distribution System
Air Inlet Filter
Air Filter
Compressor Package Enclosure
Aftercooler and Lubricant Cooler
Pneumatic Tool
Control Panel
Filter, Regulator, and Lubricator
Motor
Compressor Air End
Lubricant/Air Separator

Basic of Pneumatics

Air

The earth is surrounded by an envelope of air known as atmosphere. The composition of this 12 mile thick envelope is shown in the figure.
Due to the compressibility of air, increasing the pressure causes decrease in the volume of air.





32 degrees Celcius 90% RH , 25.05 grams of water per meter cube

As shown in figure ACT1.1, positive-displacement compressors are available in two basic styles, reciprocating and rotary. Each of these basic styles is then further segmented by different technologies.

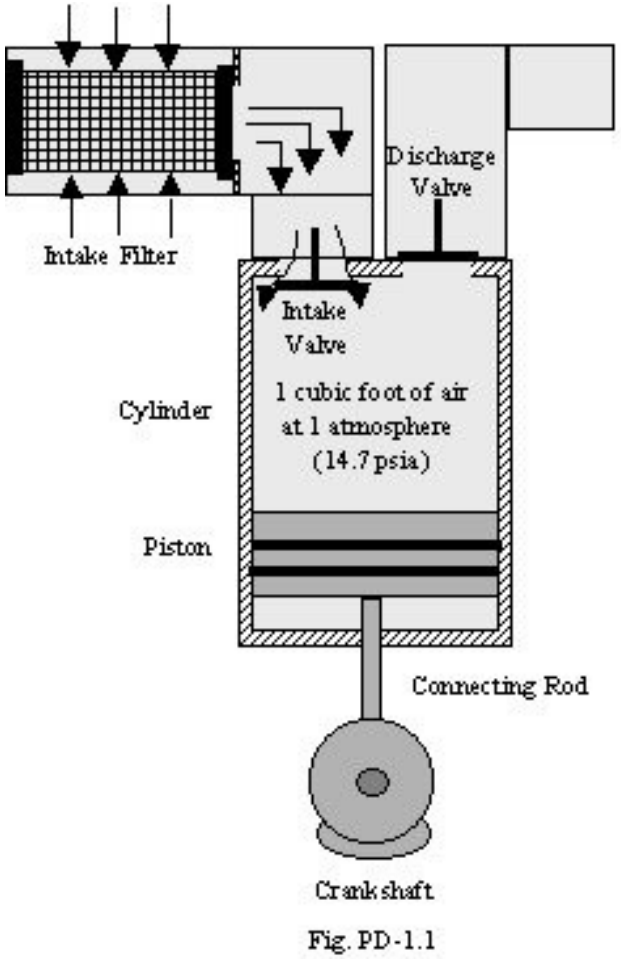


Fig. PD-1.1

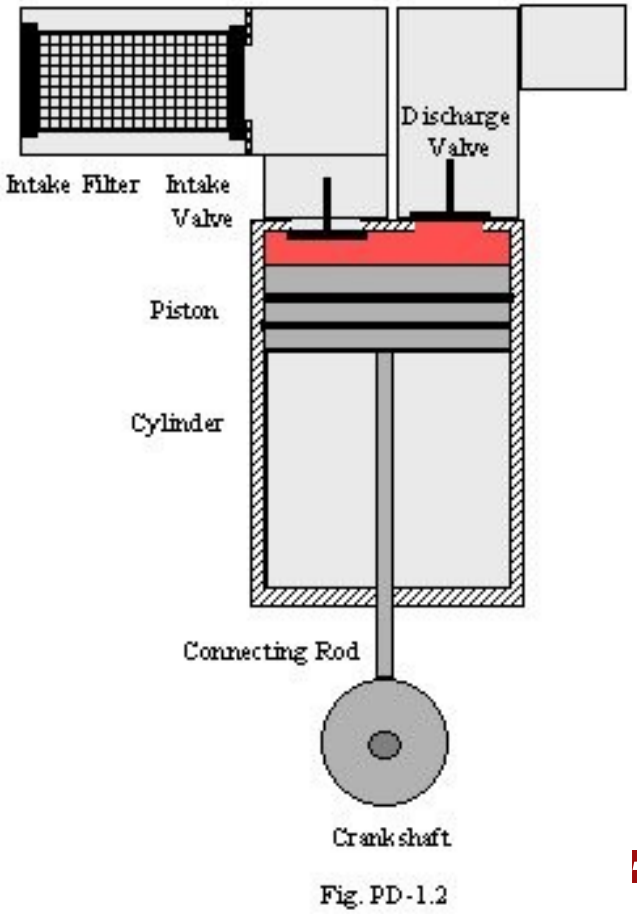


Fig. PD-1.2

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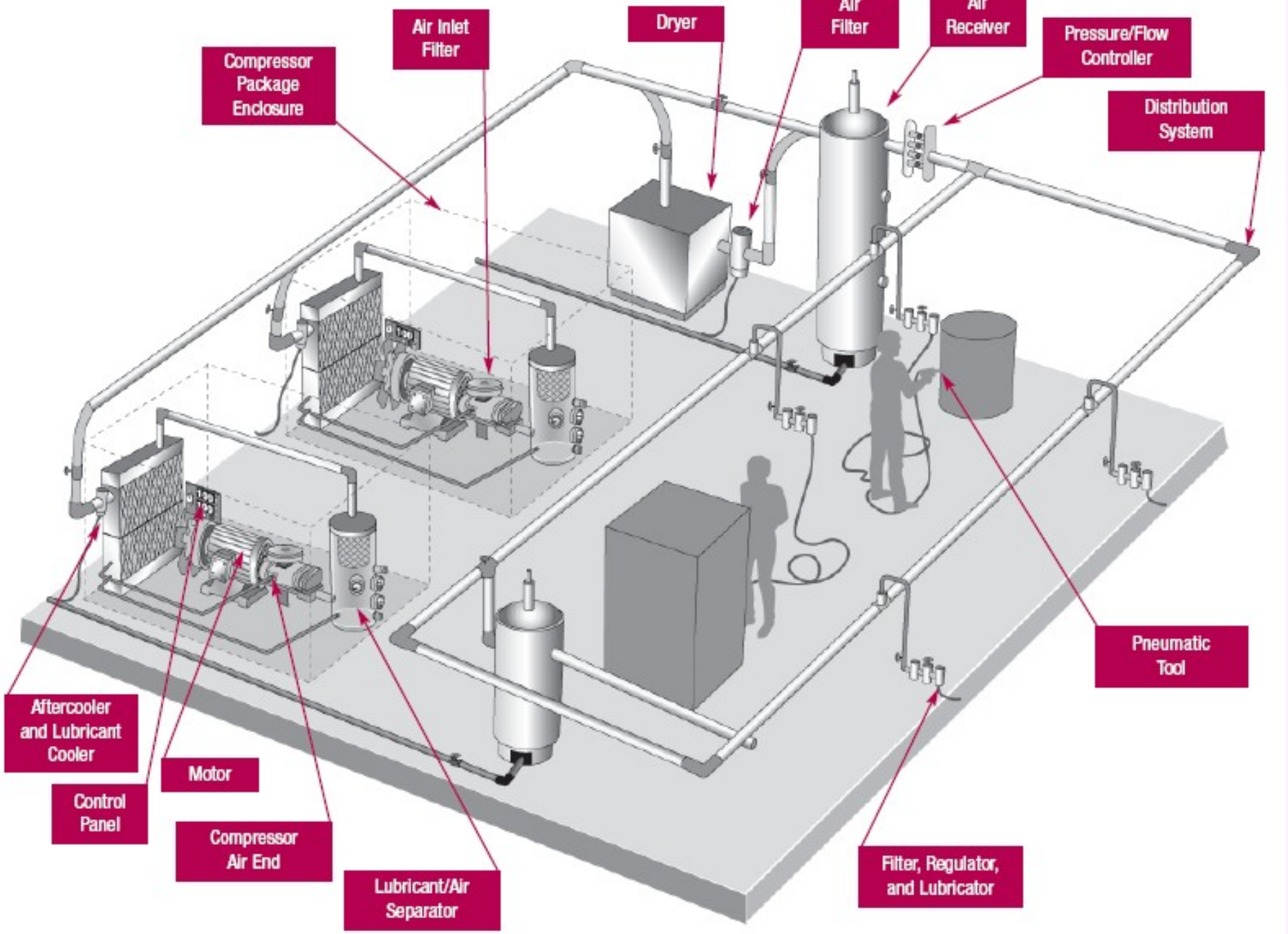
Air Inlet Filter
Dryer
Air Filter
Air Receiver
Pressure/Flow Controller
Compressor Package Enclosure
Distribution System
Pneumatic Tool
Aftercooler and Lubricant Cooler
Motor
Control Panel
Compressor Air End
Lubricant/Air Separator
Filter, Regulator, and Lubricator

POSITIVE DISPLACEMENT COMPRESSOR

- **RECIPROCATING**

- **ROTARY SCREW**

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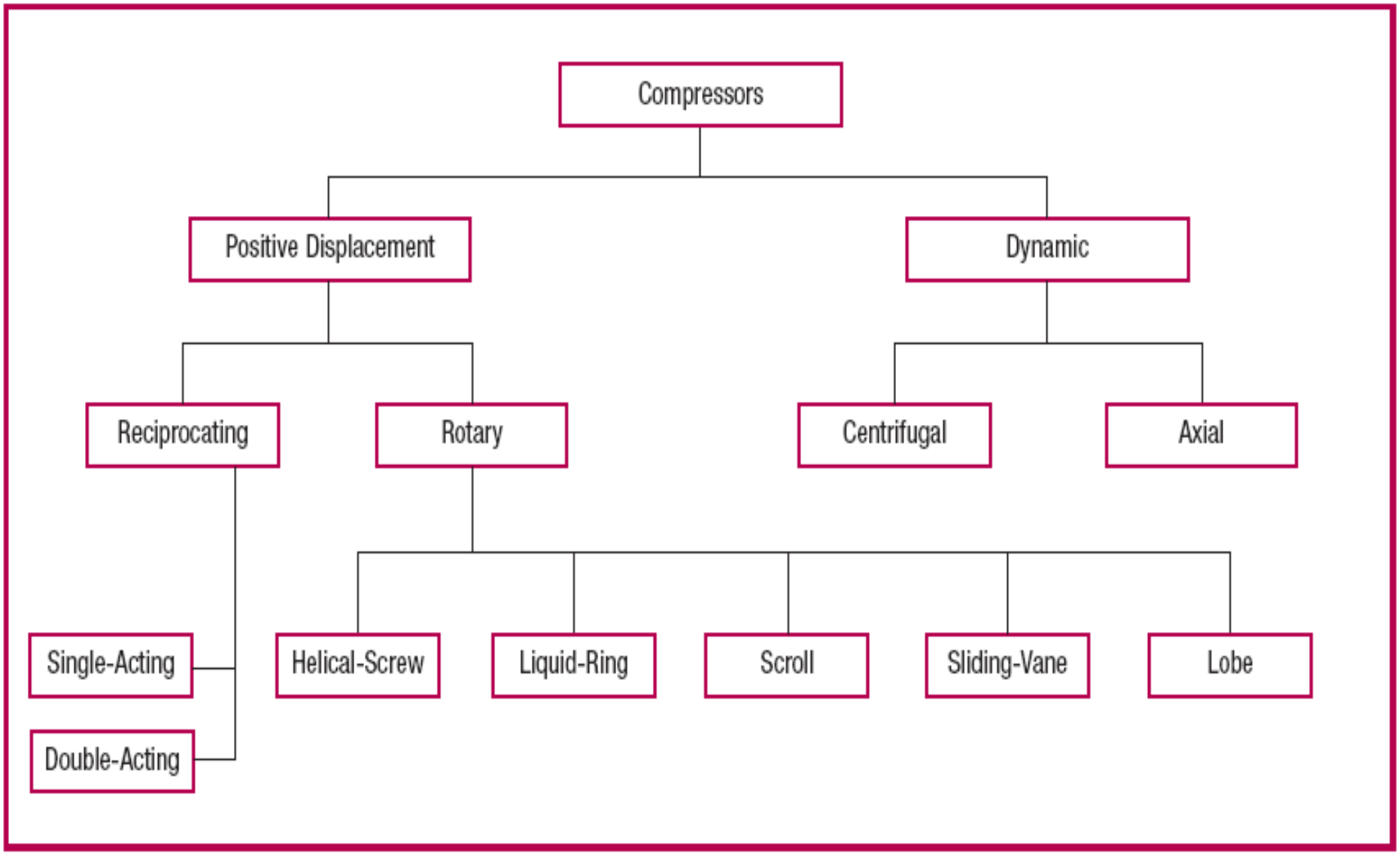

Figure 1.2 Compressor Family Tree.

COMPRESSOR PRIME MOVERS

ELECTRIC MOTOR

PETROL COMBUSTION ENGINE

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COMPRESSED AIR SYSTEM CONTROL

Are various SYSTEM CONTROLS that serve to match COMPRESSOR SUPPLY with SYSTEM DEMAND

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COMPRESSOR ACCESSORIES

- AIR INLET FILTER
- COMPRESSOR COOLING
- INTERCOOLING for multi stage
- AFTERCOOLERS (fan cooled / watercooled)
- CONDENSATE or WATER SEPARATORS
- AIR RECEIVER
- COMPRESSED AIR DRYERS
- VARIOUS FILTERS (mainline / end-use)
- Shut-off & by-pass VALVES
- REGULATING VALVES
- DISTRIBUTION (pipings)
- INSTRUMENTATION

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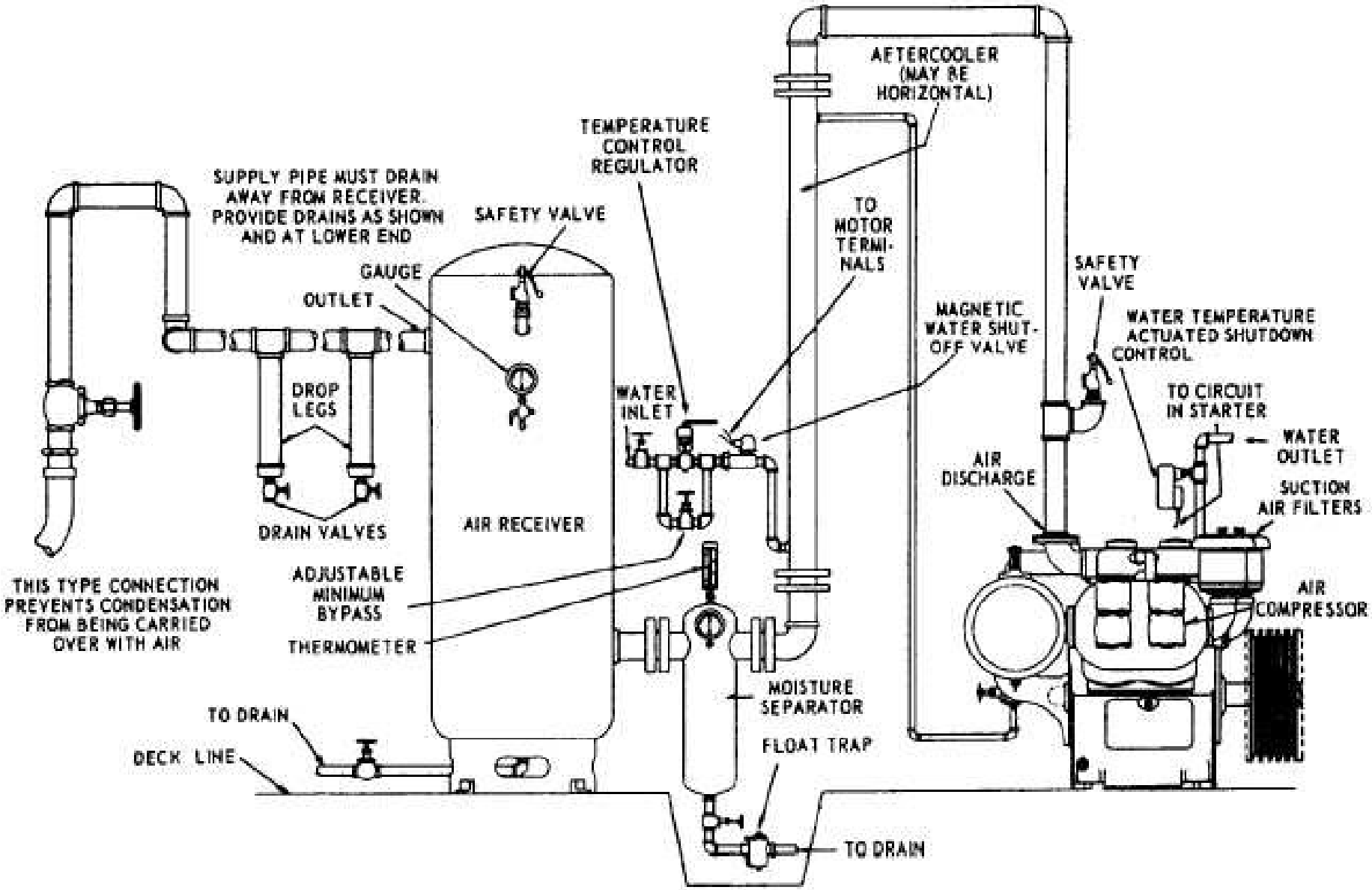
AFTERCOOLER (MAY BE HORIZONTAL)
TEMPERATURE CONTROL REGULATOR
SUPPLY PIPE MUST DRAIN AWAY FROM RECEIVER. PROVIDE DRAINS AS SHOWN AND AT LOWER END
SAFETY VALVE
TO MOTOR TERMI-NALS
SAFETY VALVE
GAUGE
OUTLET
MAGNETIC WATER SHUT-OFF VALVE
WATER TEMPERATURE ACTUATED SHUTDOWN CONTROL
DROP LEGS
WATER INLET
TO CIRCUIT IN STARTER
WATER OUTLET
AIR DISCHARGE
SUCTION AIR FILTERS
DRAIN VALVES
AIR RECEIVER
THIS TYPE CONNECTION PREVENTS CONDENSATION FROM BEING CARRIED OVER WITH AIR
ADJUSTABLE MINIMUM BYPASS
AIR COMPRESSOR
THERMOMETER
MOISTURE SEPARATOR
TO DRAIN
FLOAT TRAP
DECK LINE
TO DRAIN

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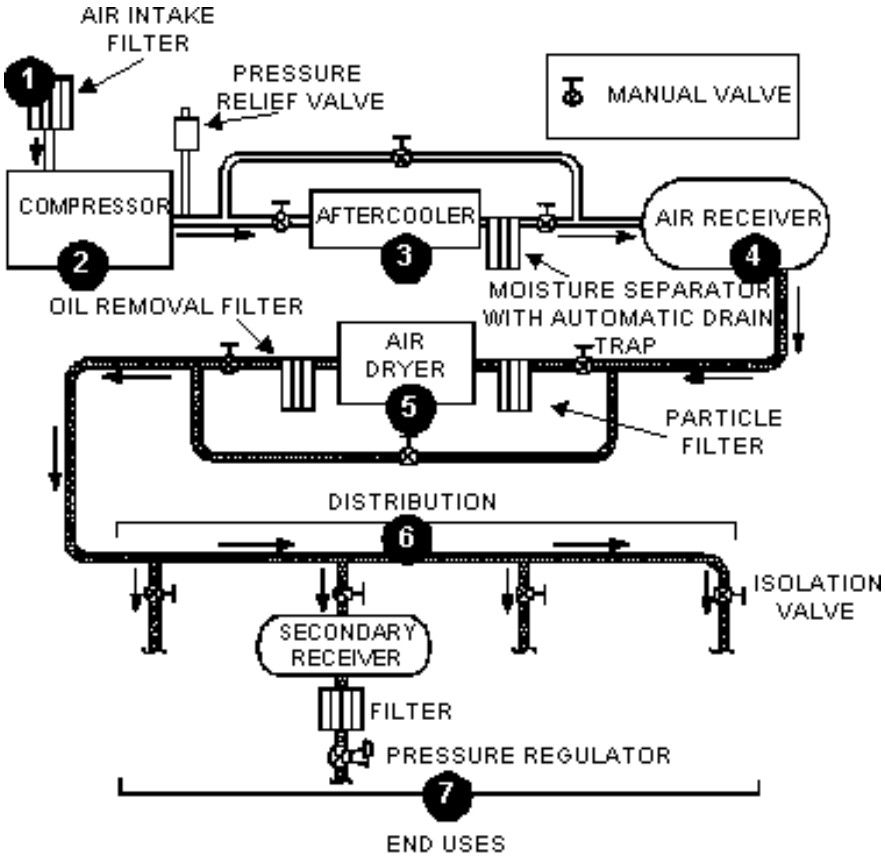
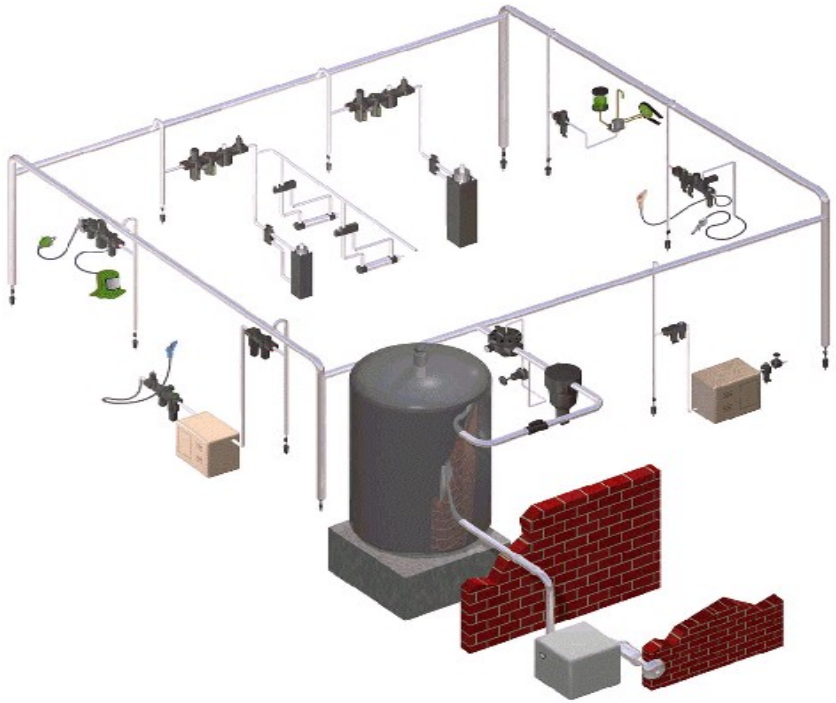
AIR INLET FILTER





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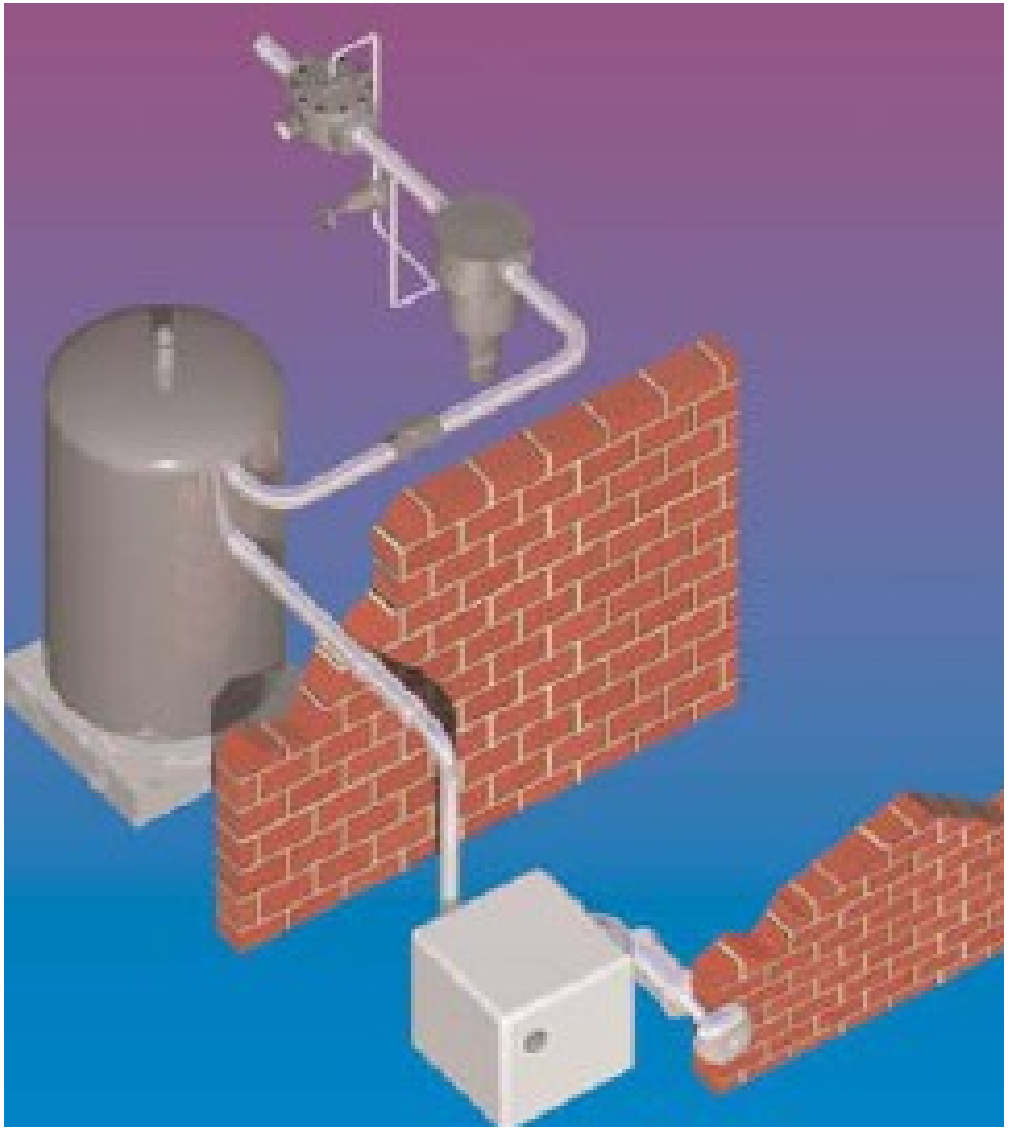
AIR INLET FILTER



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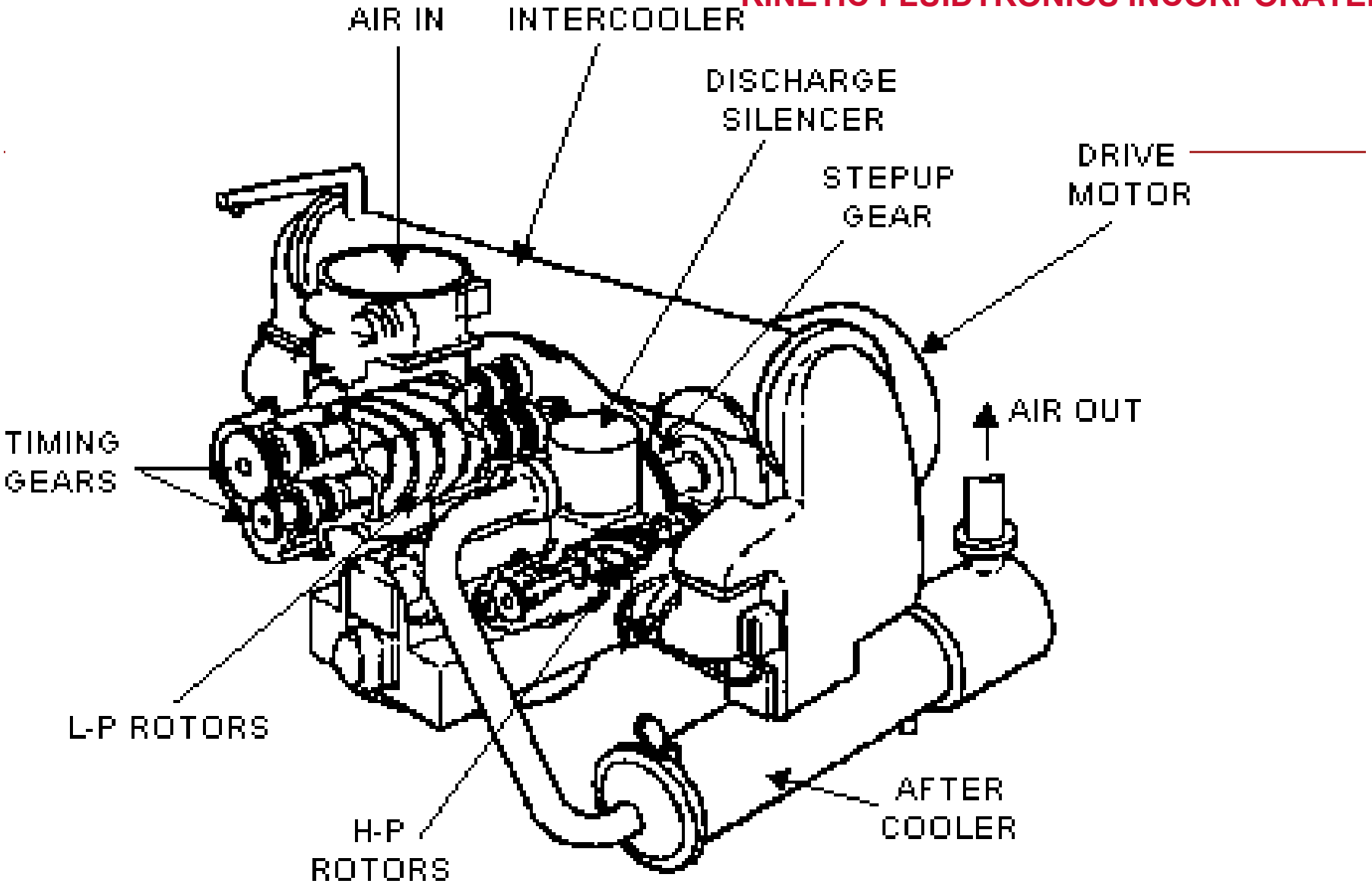
AIR IN
INTERCOOLER
DISCHARGE SILENCER
STEPUP GEAR
DRIVE MOTOR
AIR OUT
TIMING GEARS
L-P ROTORS
H-P ROTORS
AFTER COOLER

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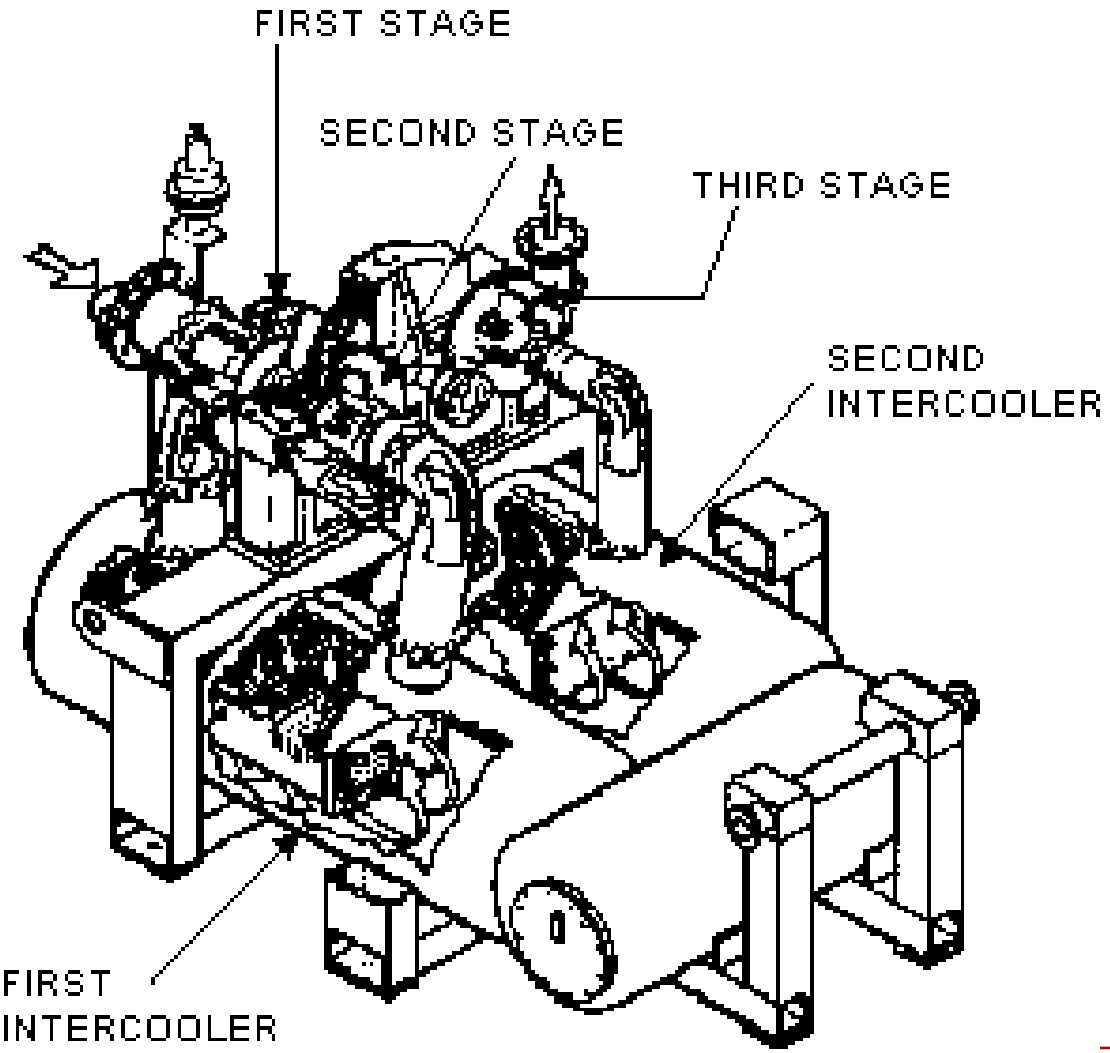
INTERCOOLING FOR MULTI STAGE COMPRESSORS



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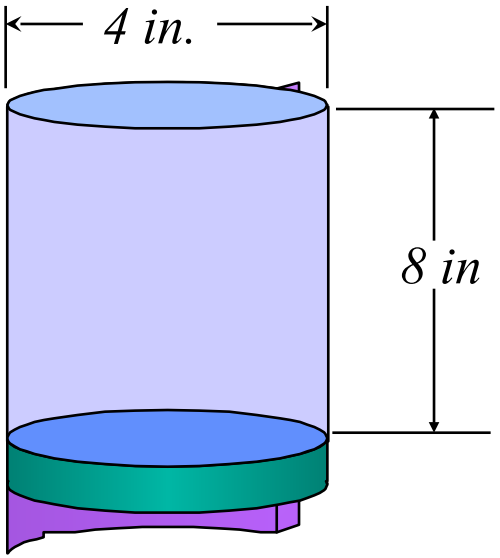
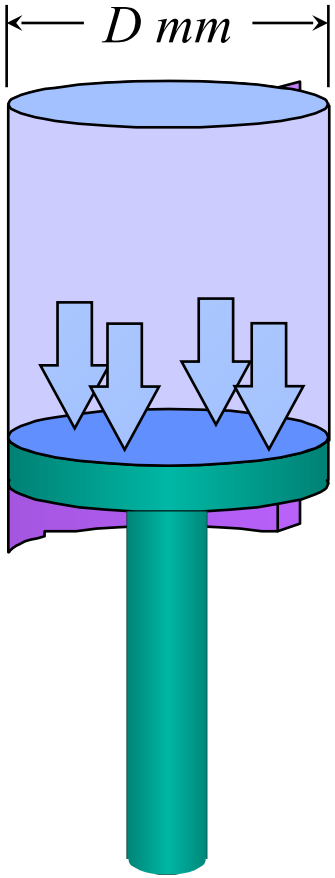
Compute for VOLUME of cylinder as shown



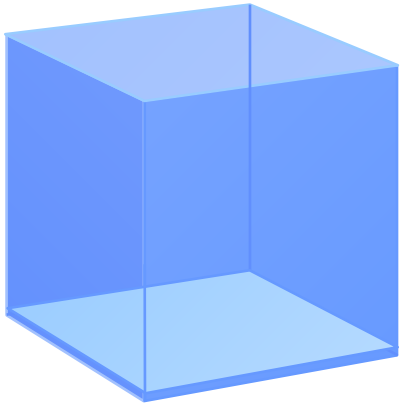


Volume = area (height)

One cubic unit of air space at varying conditions

Cubic feet

liters



Cubic meter

decimeter

Per hour

Per minute

CU.INCH DIVIDE BY
1728=CU.FEET

CU.MM DIVIDE BY
28316846=CU.FEET

multiplier

18 CU.METER PER MINUTE (35.31) = 635.58 CFM

1 CU.METER PER MINUTE = 35.31 CFM

1 decimeter per min. = 1.0 liter per min.

635.58 CFM (28.3) = 17986.91 LITERS PER MINUTE

1 CFM = 28.3 LITERS PER MINUTE

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RULE OF THUMB

A good compressor, per true HP, will deliver about 4 true CFM at 100 psig.

The tank should be sized to be at least 1 gallon of volume per CFM of the compressor.

Uncooled compressed air is hot, as much as 250 to 350 deg F!

121 to 176 degrees celcius.

Beware also, that the CFM figure given as the required air power on many tools (e.g., air chisels/hammers, sandblasters) is for an absurdly low duty cycle.

You just can't run these constantly on anything but a monster compressor, but the manufacturer still wants you to believe you can, so you will buy the tool

Reference: *Machinery's Handbook* (26th edition, see http://www.industrialpress.com/mh.htm) has an excellent section on analyzing compressed-air systems, including formulas and tables on the horsepower required to compress air, and losses in pipes and hoses. *Marks' Standard Handbook for Mechanical Engineers* describes the thermodynamics of expansion and compression of air in the section on "General Principles of Thermodynamics", subsection "Special Changes of State for Ideal Gases", item 5 "Polytropic"; and practical compressor technology in the "Pumps and Compressors" chapter.

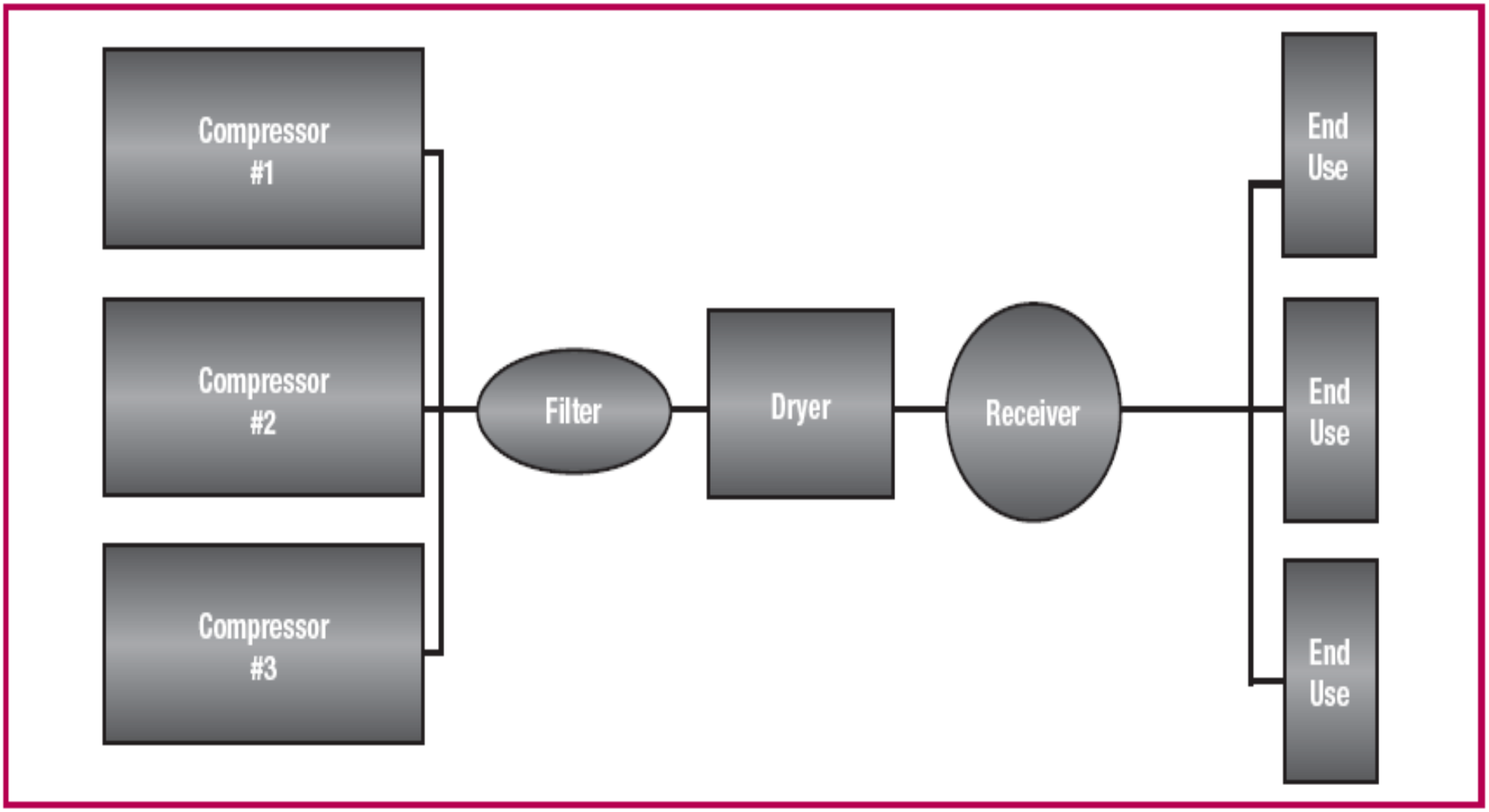

Figure 2.2 Compressed Air System Block Diagram.

Air receivers serve several important purposes.

Decrease wear and tear on the compression module, by reducing excessive compressor cycling.

Eliminate pulsations from the discharge line.

Separate some of the moisture, oil and solid particles that might be present

Help reduce dew point and temperature spikes that follow regeneration.

Offer additional storage capacity made to compensate for surges in compressed air usage.

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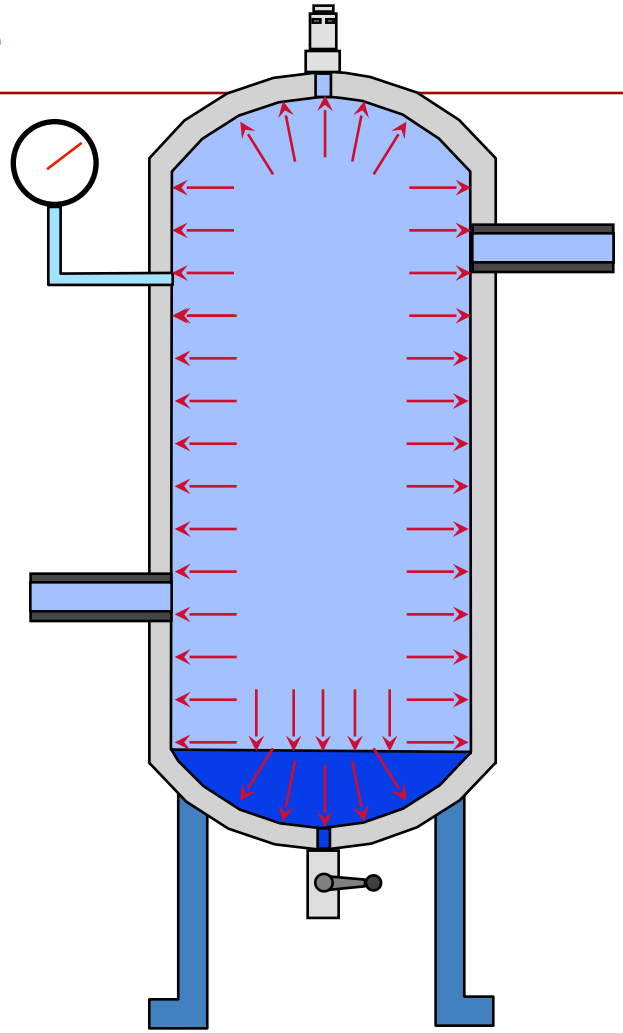
One gallon per CFM of capacity is the minimum amount of storage recommended

HANDOUTS FOR TANK SIZING

Pressure and force

- Compressed air exerts a force of constant value to every internal contact surface of the pressure containing equipment.
- Liquid in a vessel will be pressurised and transmit this force
- For every bar of gauge pressure, 10 Newtons are exerted uniformly over each square centimetre.



Why is aftercooling required?

The compressed air discharged from an air compressor is hot . Compressed air at these temperatures contains large quantities of water in vapor form. As the compressed air cools this water vapor condenses into a liquid form. As an example if an aftercooler is not used, *a 200 scfm compressor operating at 100 psig introduces 45 gallons of water into the compressed air system each day.*

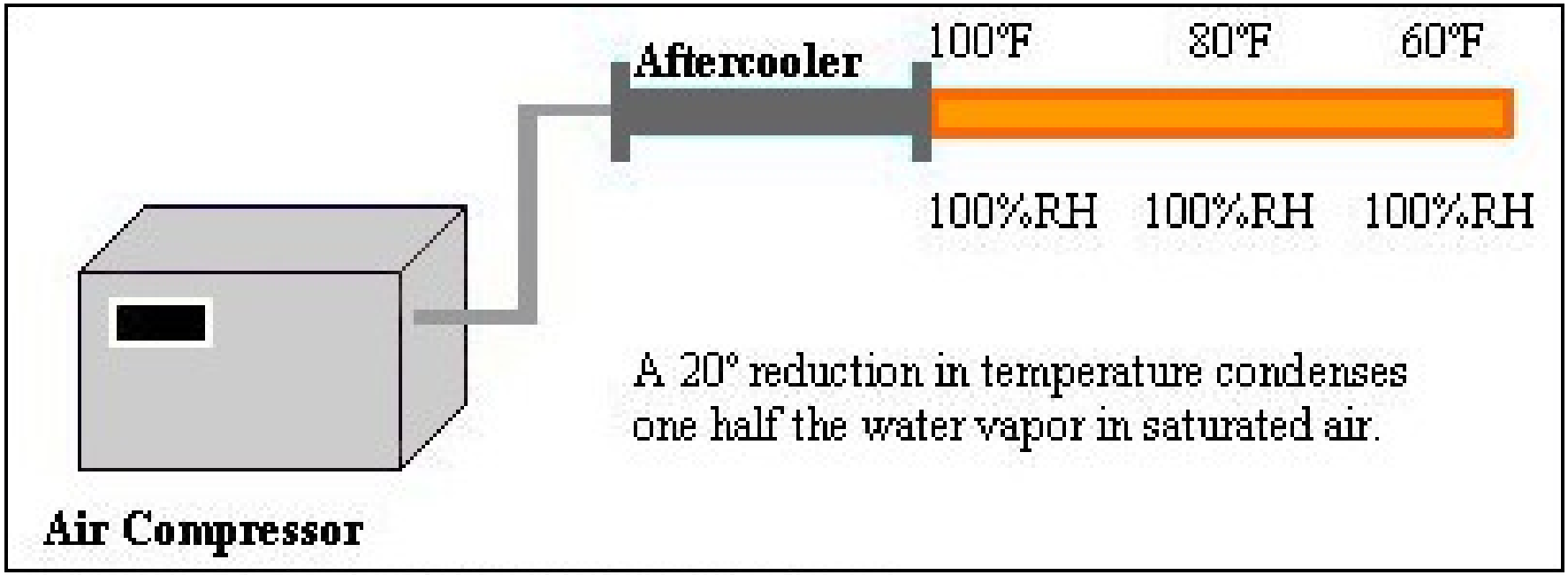


Figure CA1-7, Moisture Saturation in Compressed

Air Cooled Aftercooler

Air cooled aftercoolers (fig. AC1-2) use **ambient air** to cool the hot **compressed air**. The compressed air enters the air cooled aftercooler. compressed air travels through finned tubes or corrugated aluminum sheets of the aftercooler while ambient air is forced over the cooler by a motor-driven fan. The cooler, ambient air removes heat from the compressed air.

Figure AC 1-2
Freestanding Air-Cooled Aftercooler

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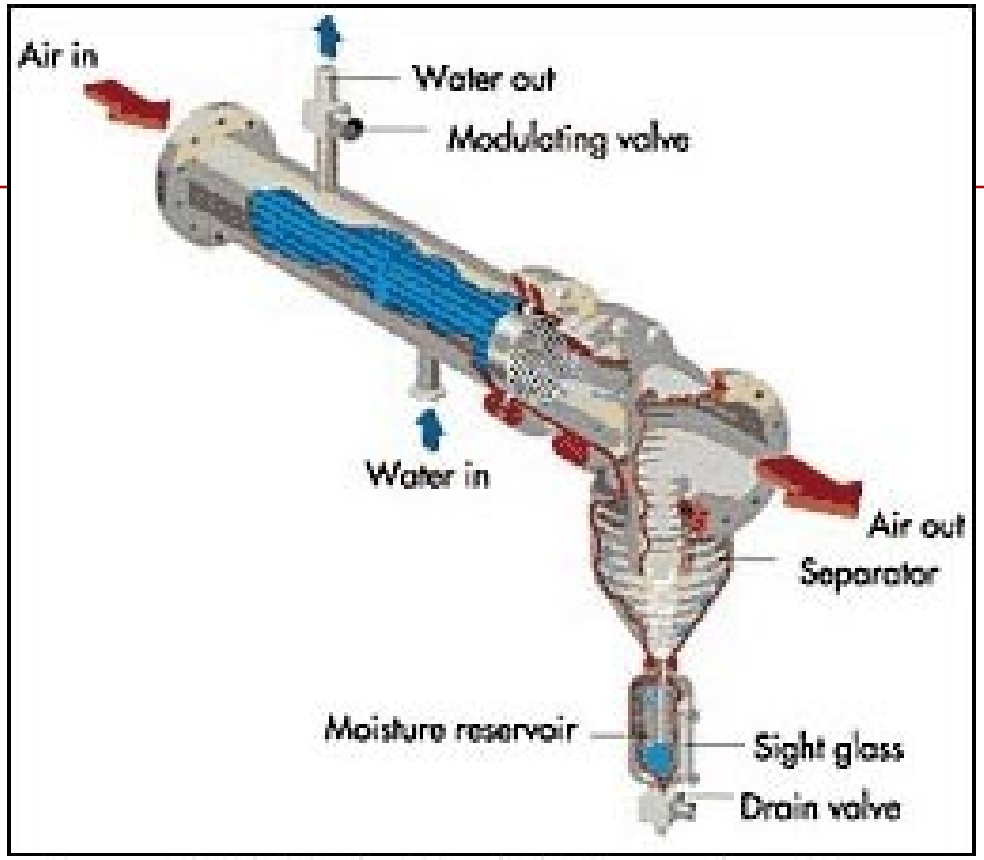


Figure AC1-3 Water-Cooled Aftercooler with Moisture Separator and Drain Valve. Courtesy of Compressor Engineering Div. Of Amco Industries,

The disadvantages of a water-cooled aftercooler include high water usage and difficult heat recovery. Advantages to using a water-cooled aftercooler include better heat transfer and no required electricity.

A moisture separator installed at the discharge of the aftercooler removes most of the liquid moisture and solids from the compressed air. Utilizing centrifugal force, moisture and solids collect at the bottom of the moisture separator. An automatic drain should be used to remove the moisture and solids.

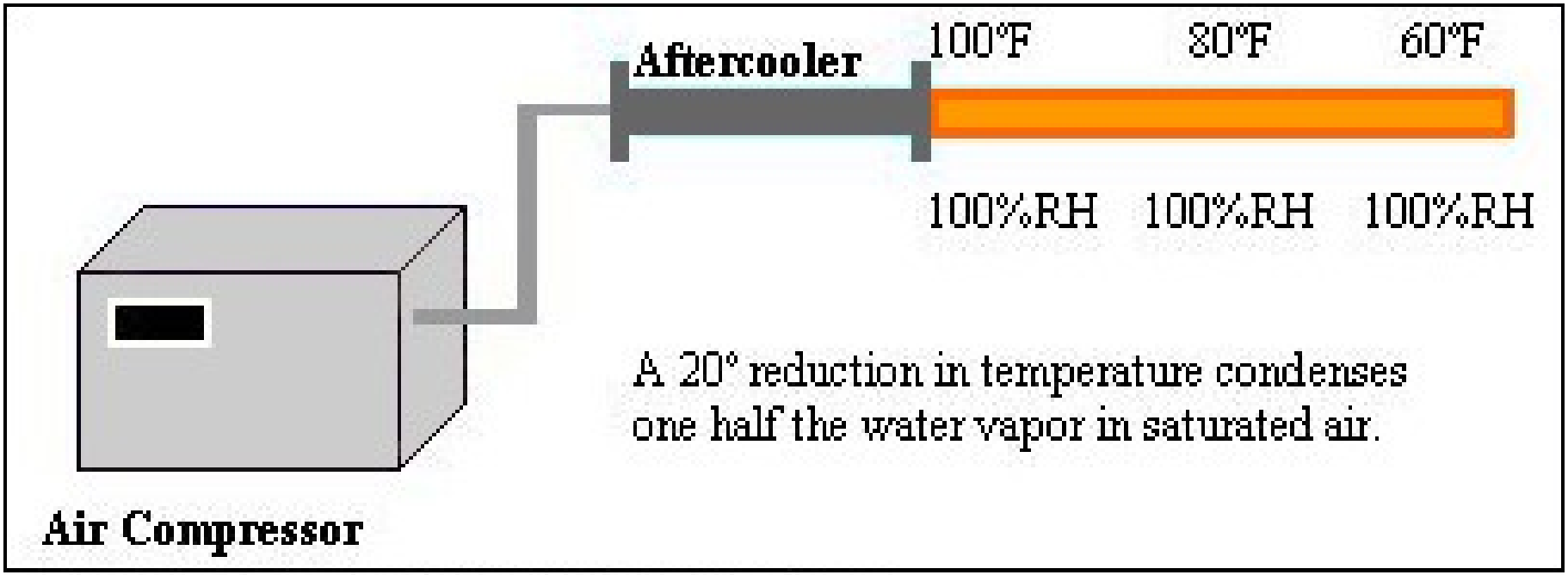
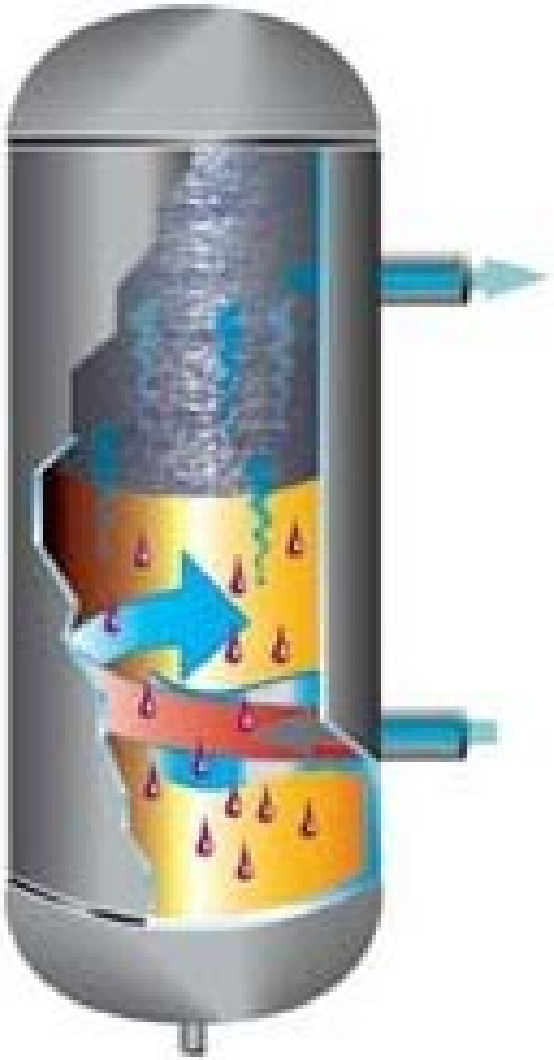
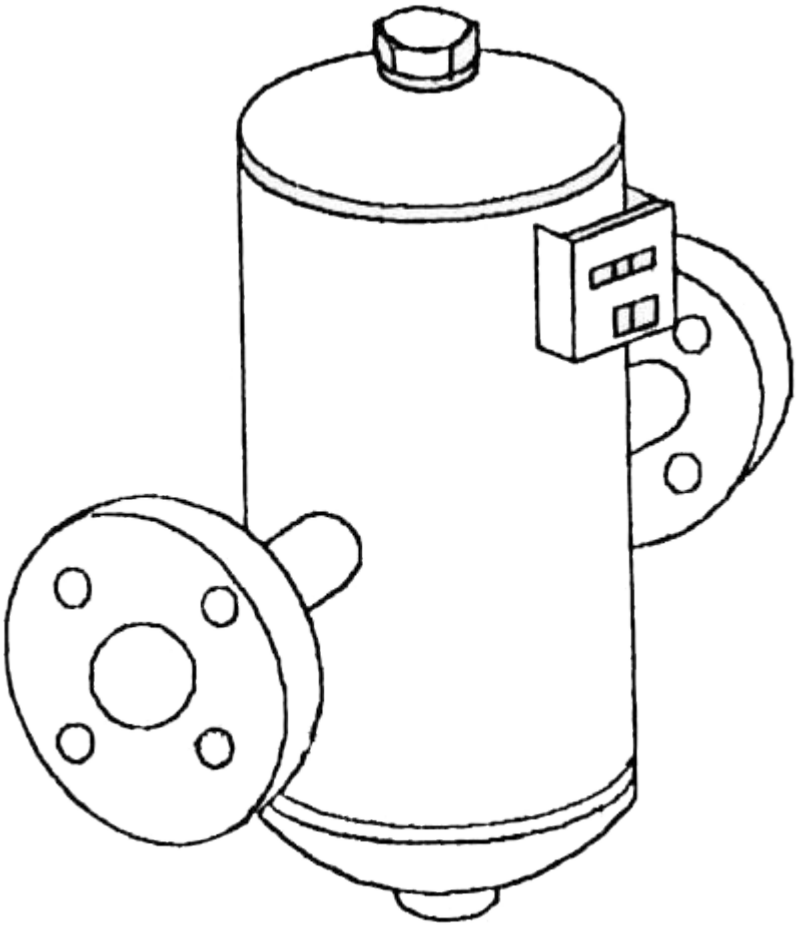


Figure CA1-7, Moisture Saturation in Compressed

WATER SEPARATOR





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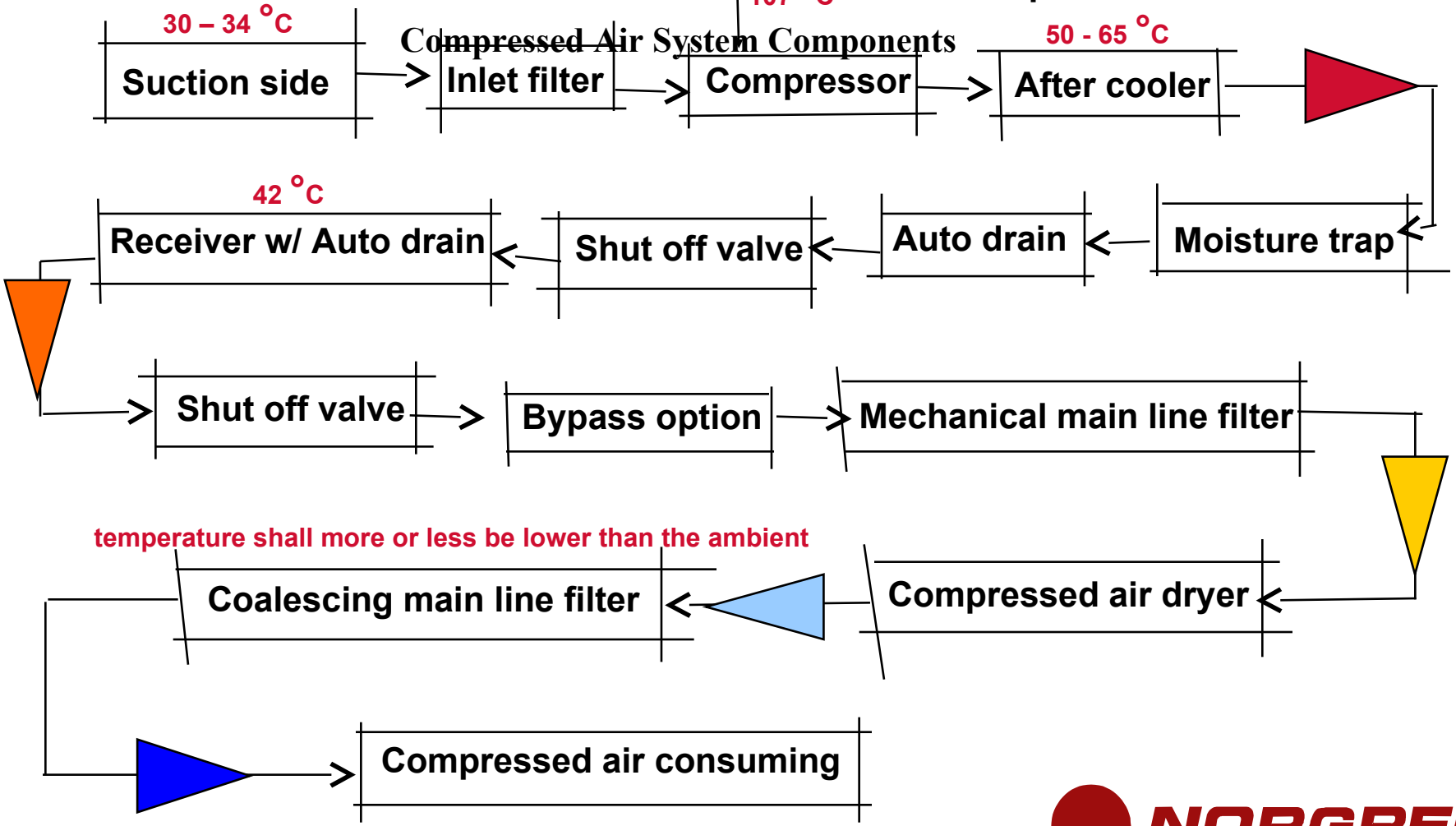
Temperature at discharge

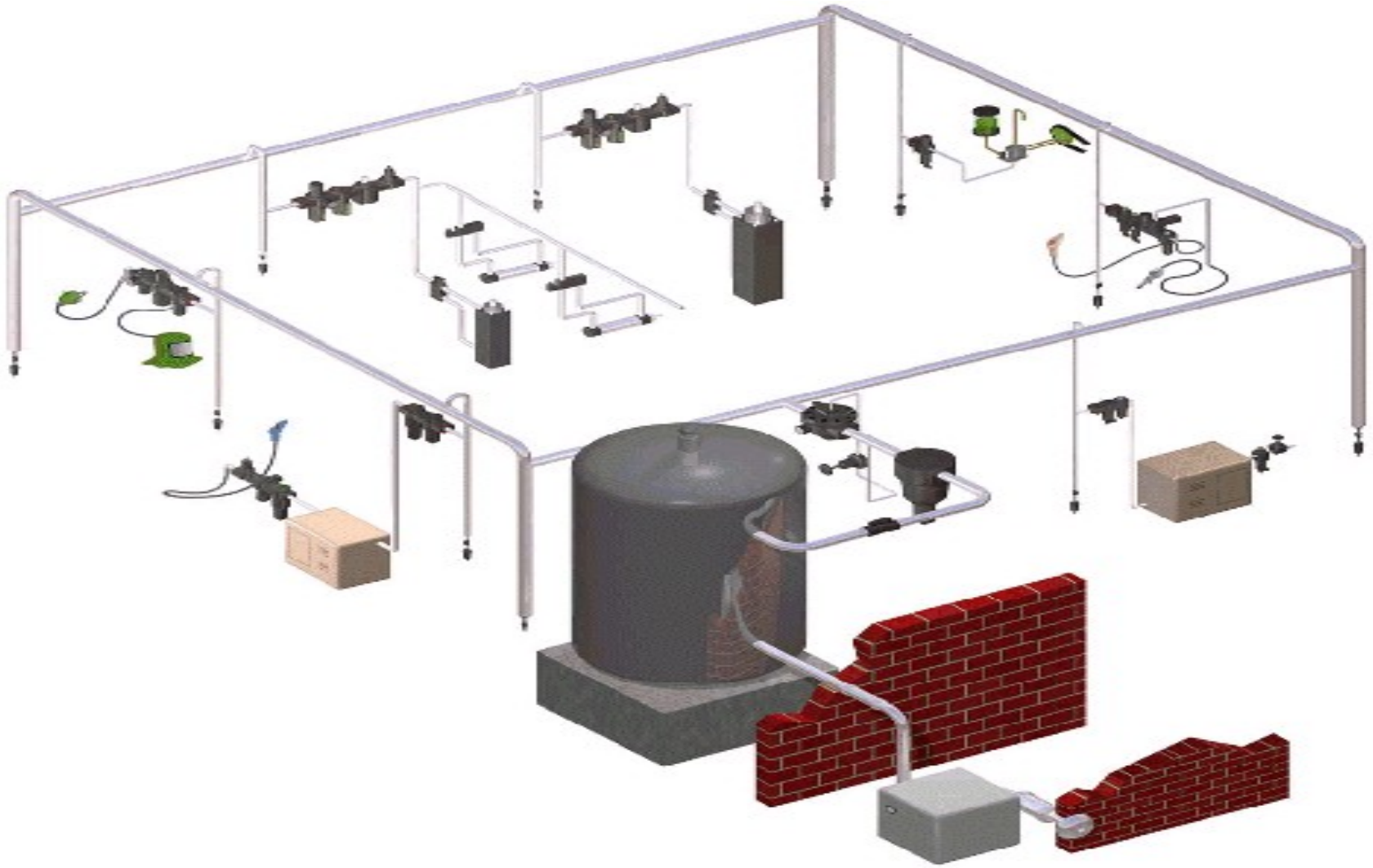
- 93.3 °C Oil flooded rotary
- 176 °C Oil free rotary
- 148 °C 2 stage reciprocating
- 107 °C Vane compressors

Compressed Air System Components



NORGREN

Typical compressed air facility



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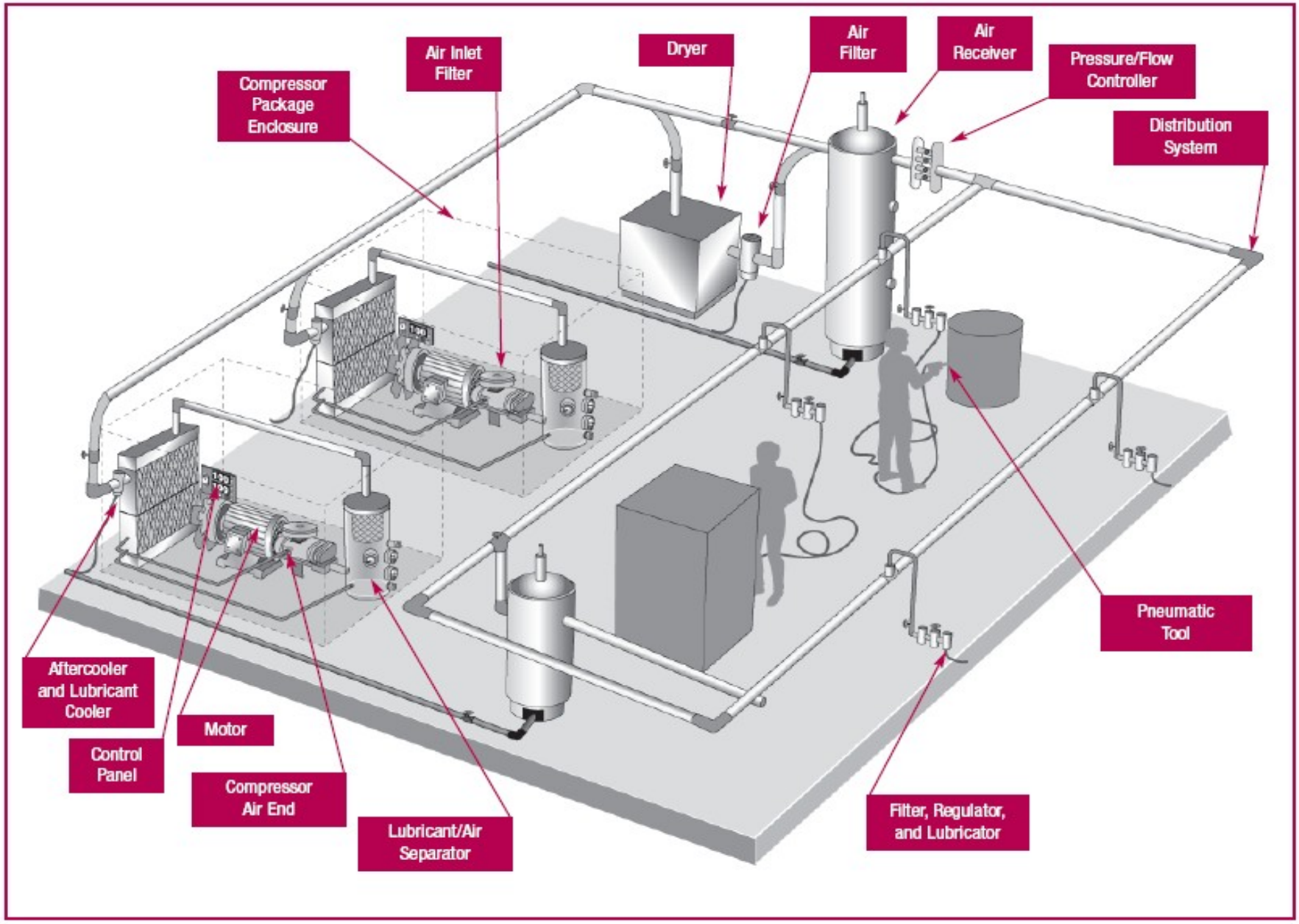


Figure 1.1 Components of a Typical Industrial Compressed Air System.

50% RH

65% RH

90% RH

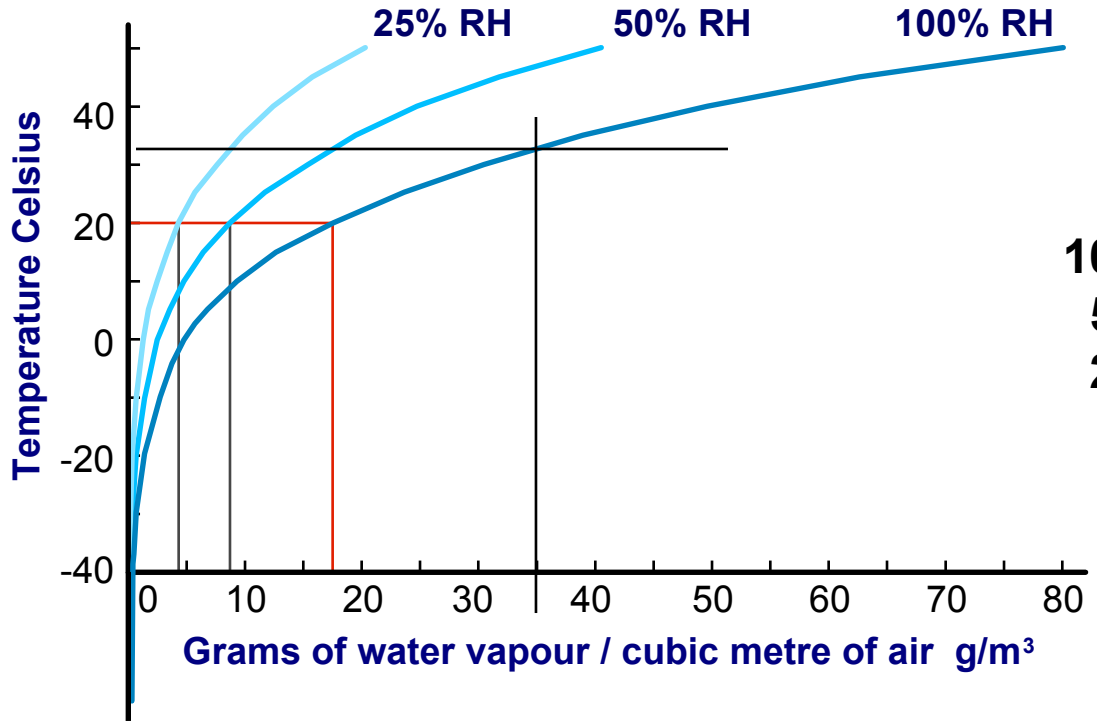
Here in the Philippines our RELATIVE HUMIDITY averages whole year round at 90% RH.

Different global regions has different RELATIVE HUMIDITY.

Country 1 has less water in air than Country 3

Air cooled to a lower temperature

- The amount of water vapour contained in a sample of the atmosphere is measured as relative humidity %RH. This percentage is the proportion of the maximum amount that can be held at the prevailing temperature.



At 20° Celsius
100% RH = 17.4 g/m³
50% RH = 8.7 g/m³
25% RH = 4.35 g/m³

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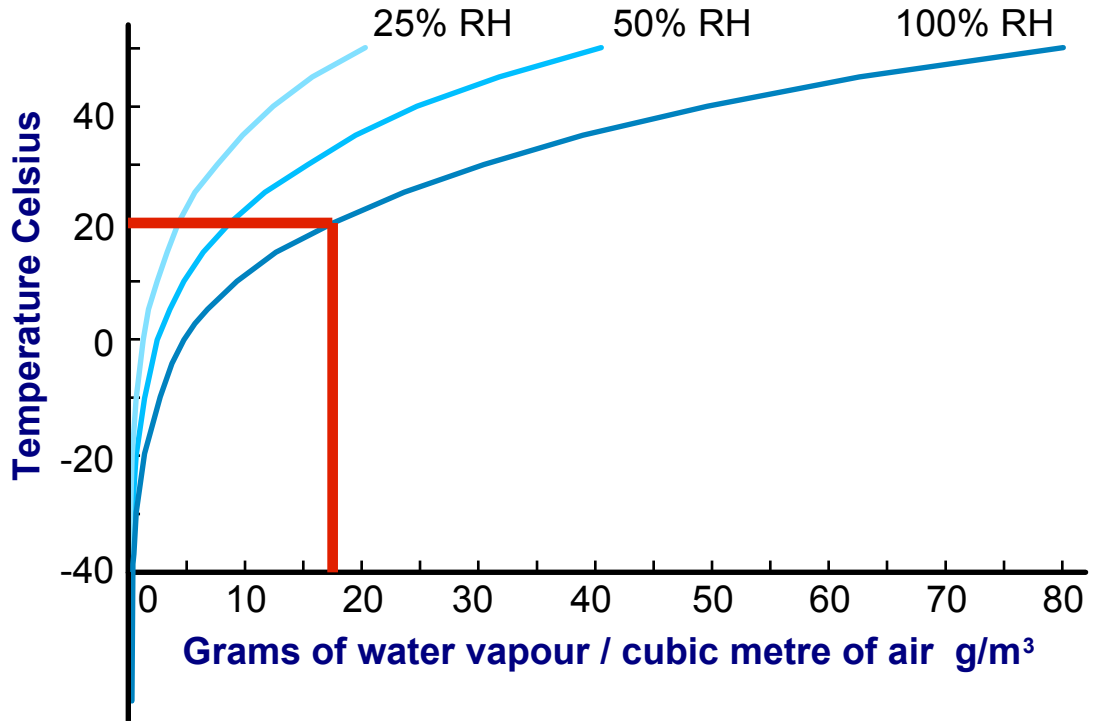
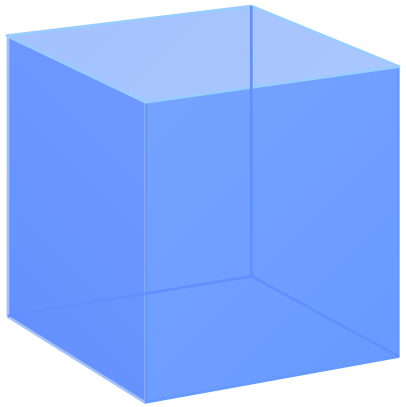
Air cooled to a lower temperature

- **If 1 cubic metre of fully saturated compressed air (100 % RH) is cooled to just above freezing point, approximately 75% of the vapour content will be condensed out. When it is warmed back to 20°C it will be dried to nearly 25% RH**





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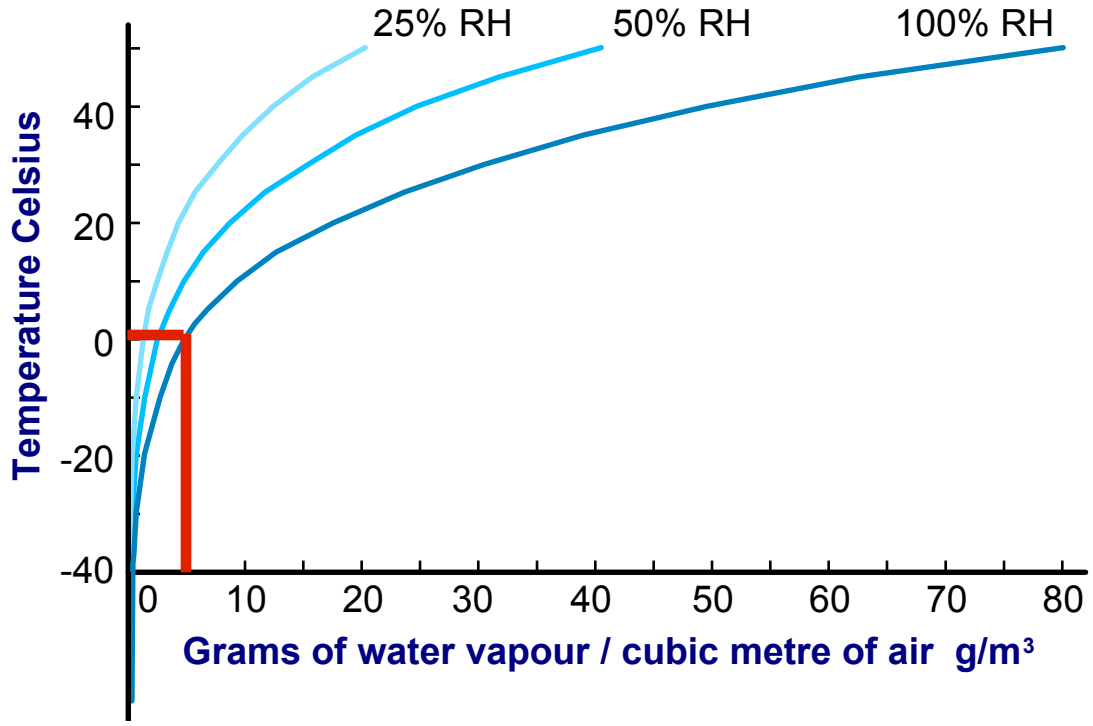
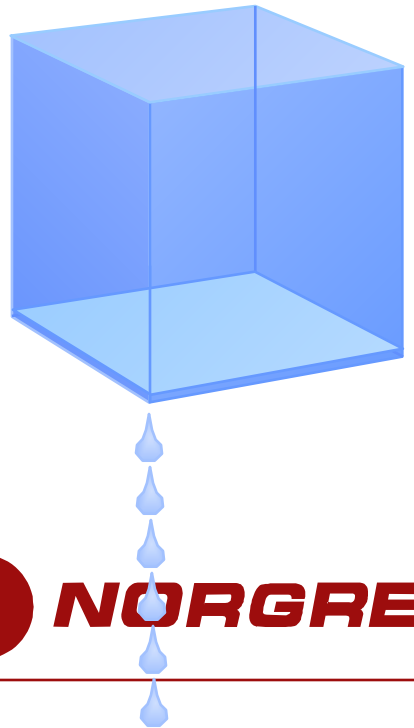
Low temperature drying

- **If 1 cubic metre of fully saturated compressed air (100 % RH) is cooled to just above freezing point, approximately 75% of the vapour content will be condensed out. When it is warmed back to 20°C it will be dried to nearly 25% RH**





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Low temperature drying

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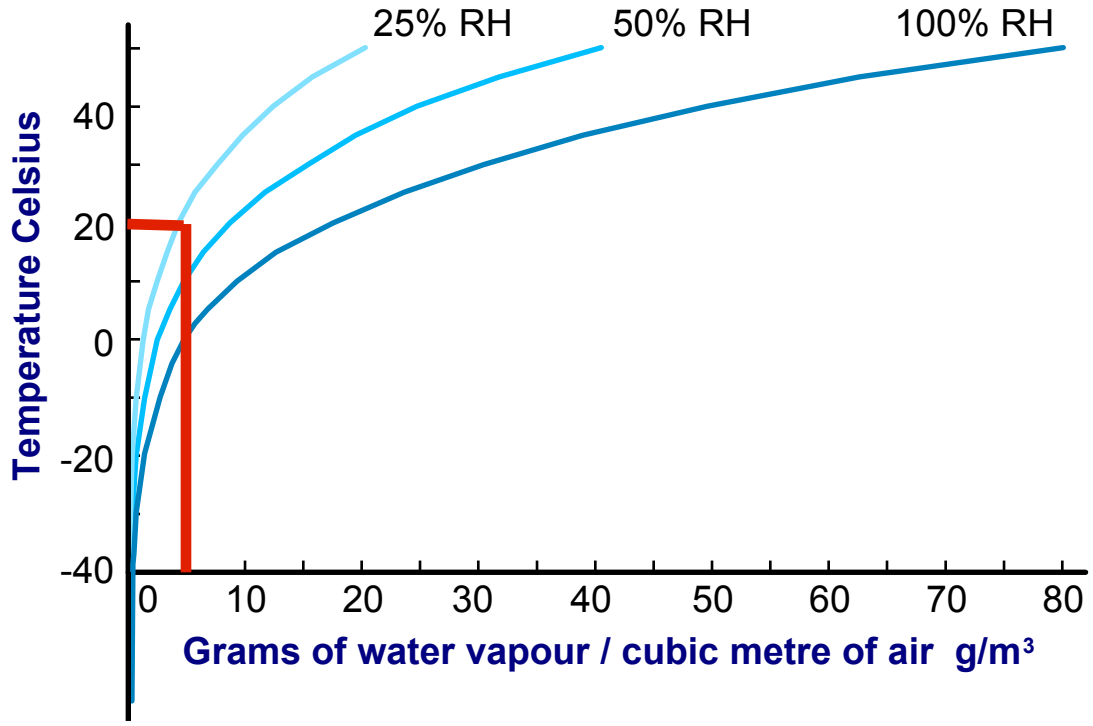

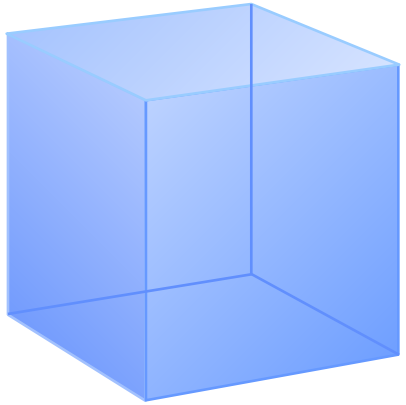

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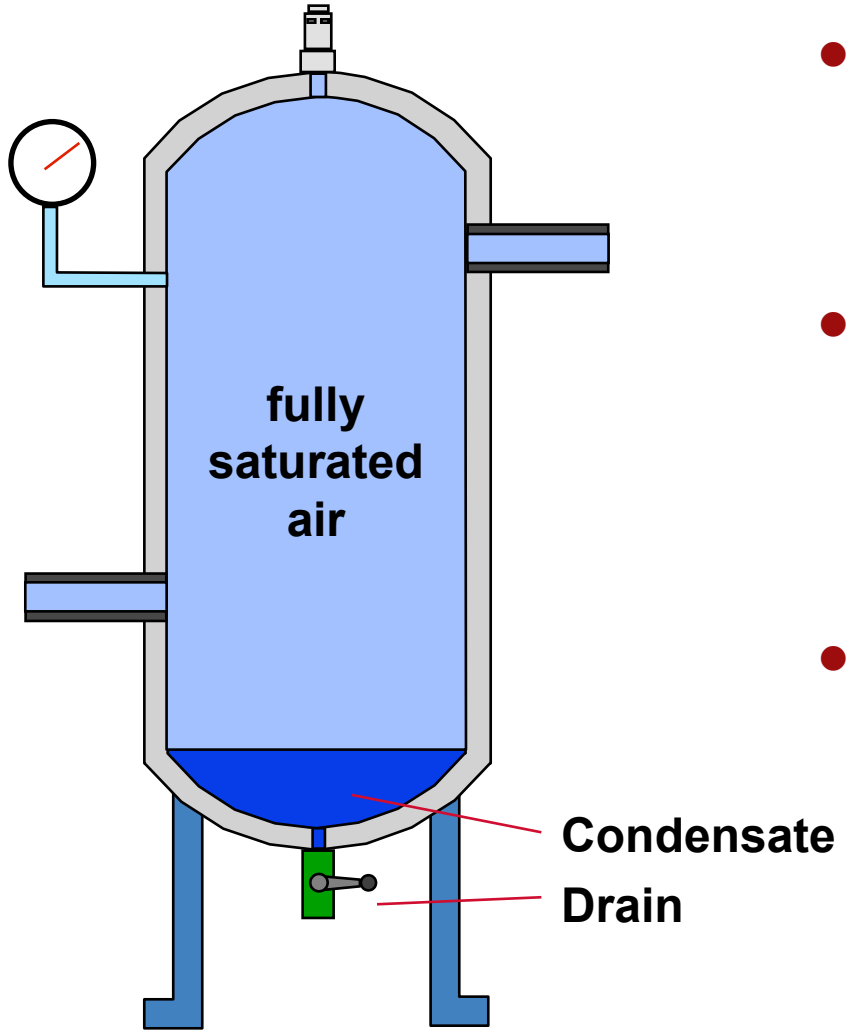
Water in compressed air



- When large quantities of air are compressed, noticeable amounts of water are formed
- The natural moisture vapour contained in the atmosphere is squeezed out like wringing out a damp sponge
- The air will still be fully saturated (100% RH) within the receiver

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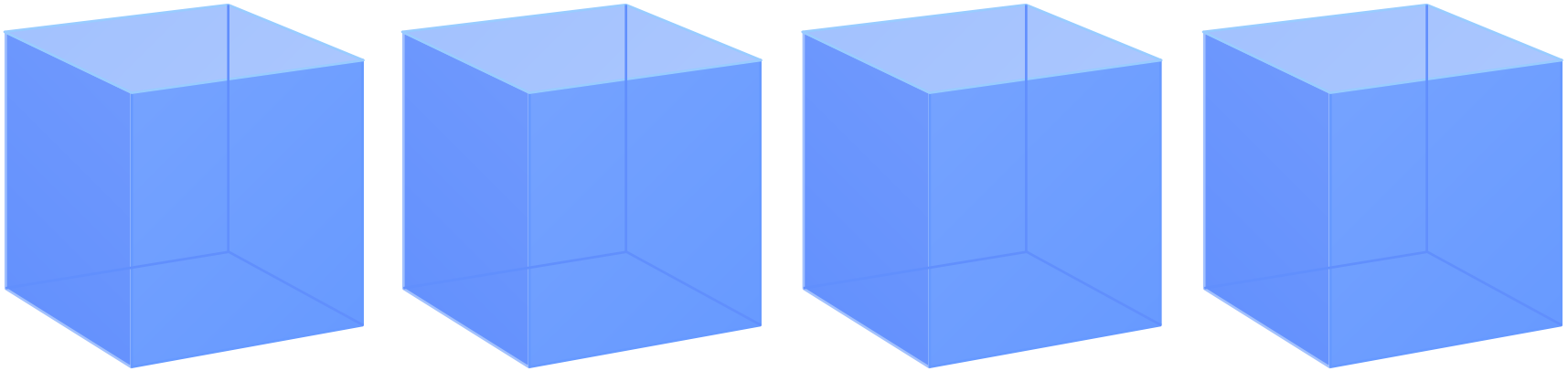
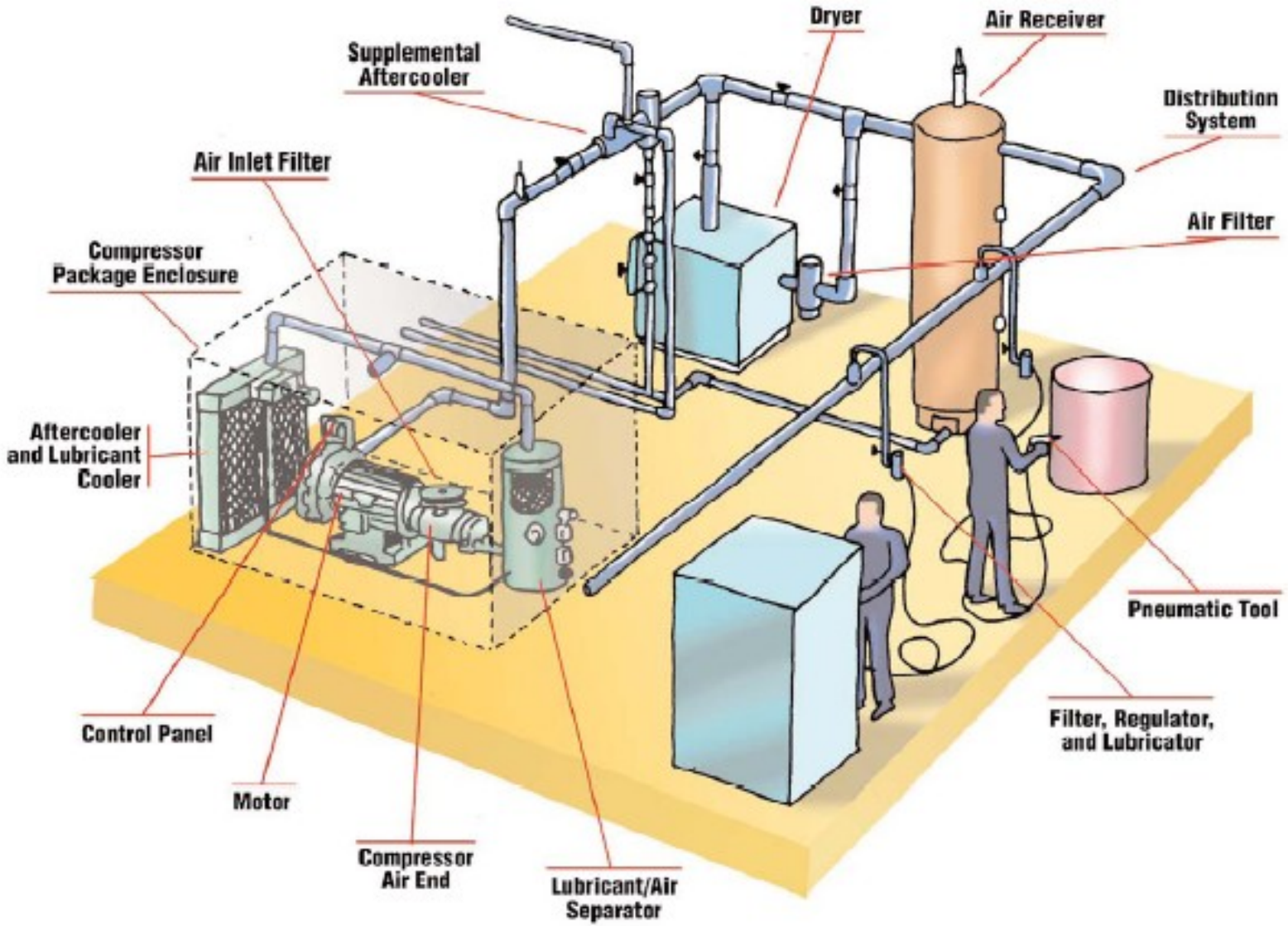
Water in compressed air

- The illustration shows four cubes each representing 1 cubic metre of atmospheric air at 20°C. Each of these volumes are at a relative humidity of 50% (50%RH). This means that they actually contain 8.7 grams of water vapour, half of the maximum possible 17.4 grams




Dryer
Air Receiver
Supplemental Aftercooler
Distribution System
Air Inlet Filter
Air Filter
Compressor Package Enclosure
Aftercooler and Lubricant Cooler
Pneumatic Tool
Control Panel
Filter, Regulator, and Lubricator
Motor
Compressor Air End
Lubricant/Air Separator

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TYPES OF COMPRESSED AIR DRYER

Figure AD1-4, Dual Tower Desiccant Air Dryer

Figure AD1-3, Non-Cycling Refrigerated Air Dryer

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COMPRESSED AIR DRYER

Have different operating characteristics and degrees of DEWPOINT

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Compressed air DRYER RATINGS

Are usually based on STANDARD DRYER INLET CONDITIONS

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KINETIC FLUIDTRONICS INCORPORATED

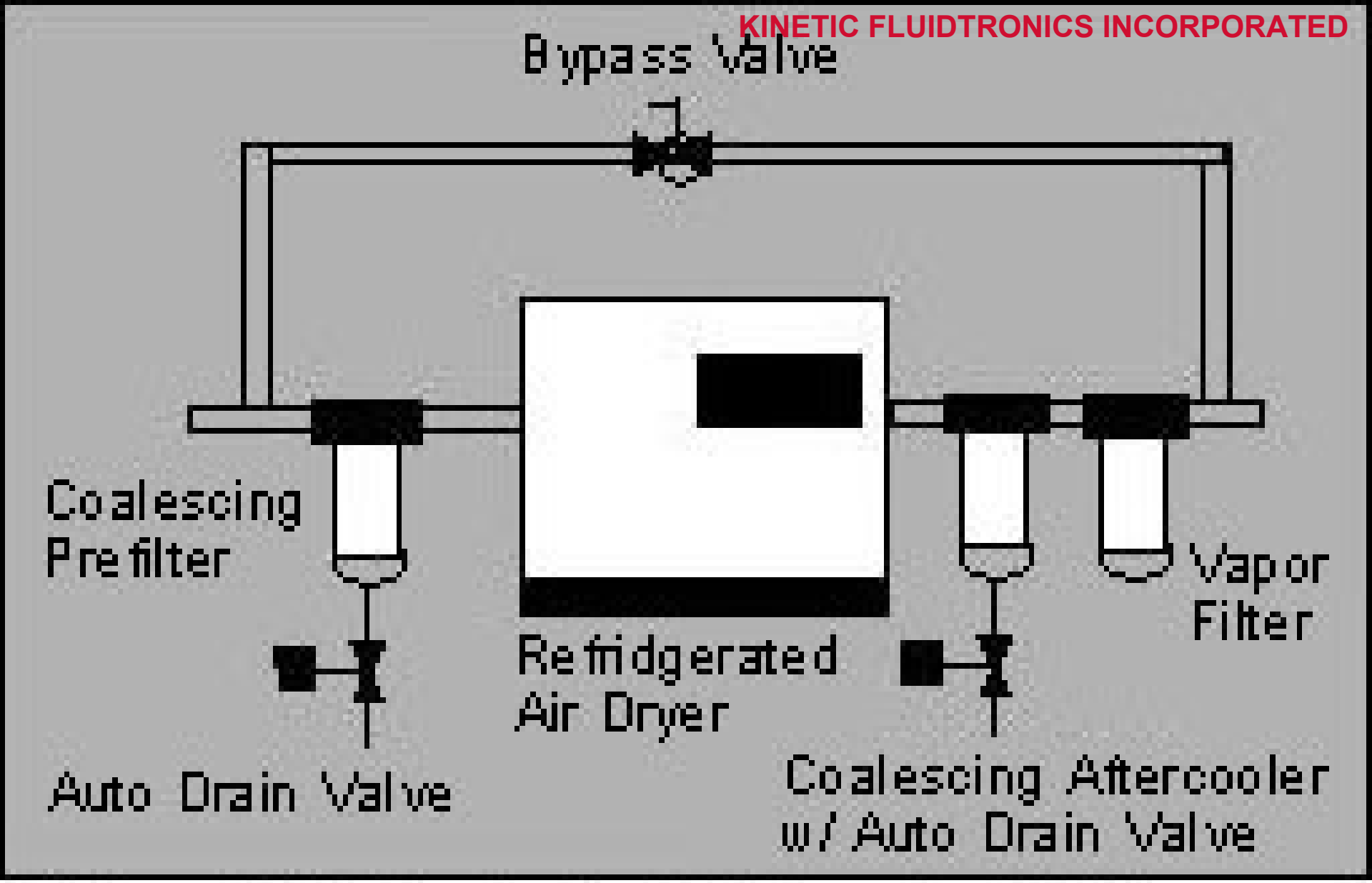
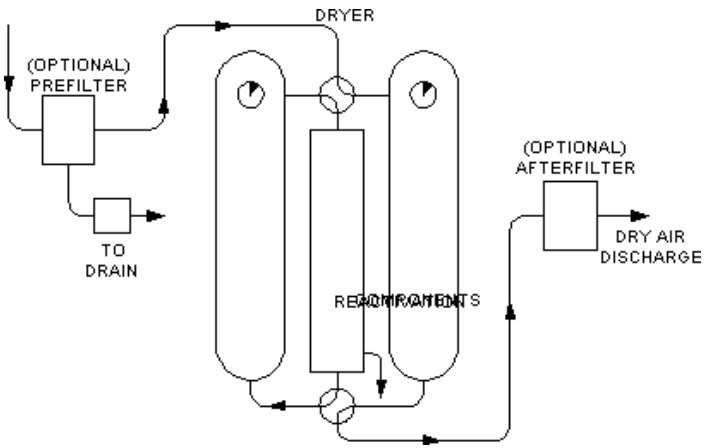


Figure AD1-21, Typical Refrigerated Air Dryer Installation Schematic

REGENERATIVE DESSICANT TYPE DRYERS

Use POROUS dessicant that ADSORBS moisture by collecting it in PORES

Silica gel
Activated alumina
Molecular sieve



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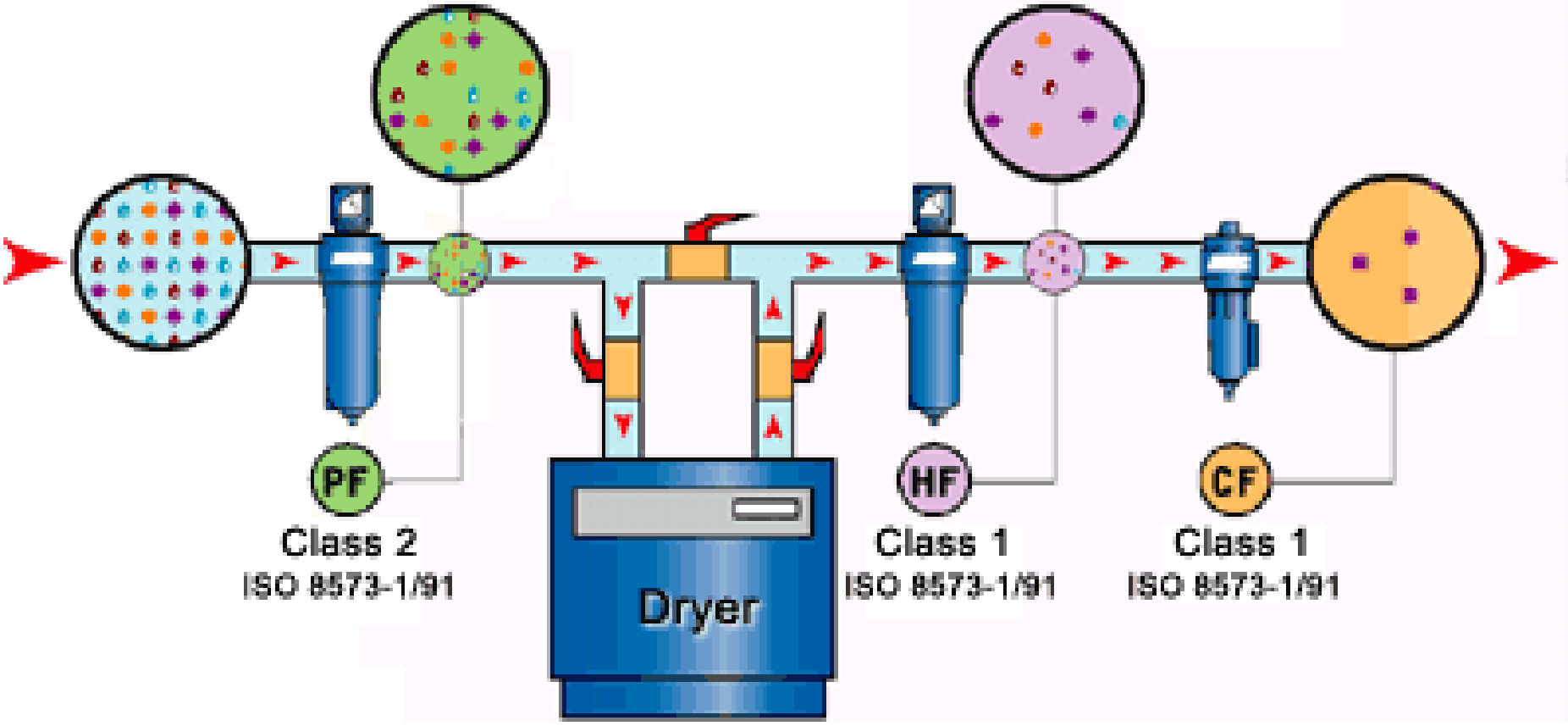
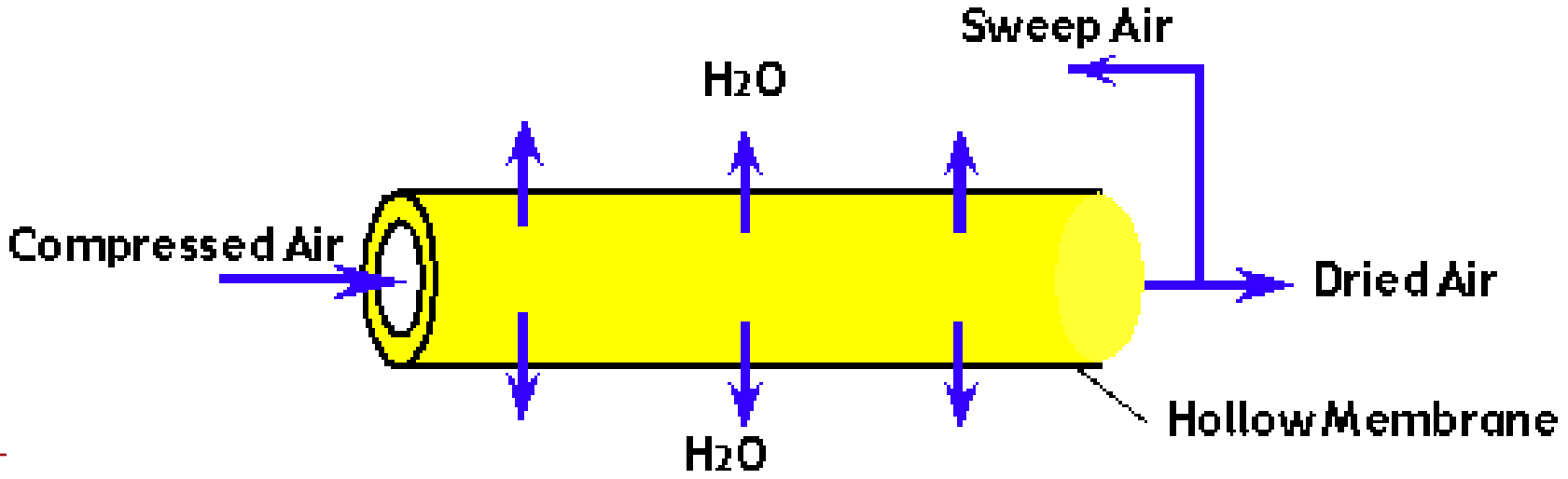
Filtration at Work:



MEMBRANE TECHNOLOGY
compressed air dryer

Use mainly for GAS SEPARATION allows molecules of certain gases to pass thru SEMI-PERMEABLE membrane fiber



Membrane dryer

MEMBRANES allow WATER VAPOR to pass thru PORES of MEMBRANE faster than other GASES

REDUCING amount of MOISTURE at AIR STREAM outlet

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Membrane technology dryer

NORGREN

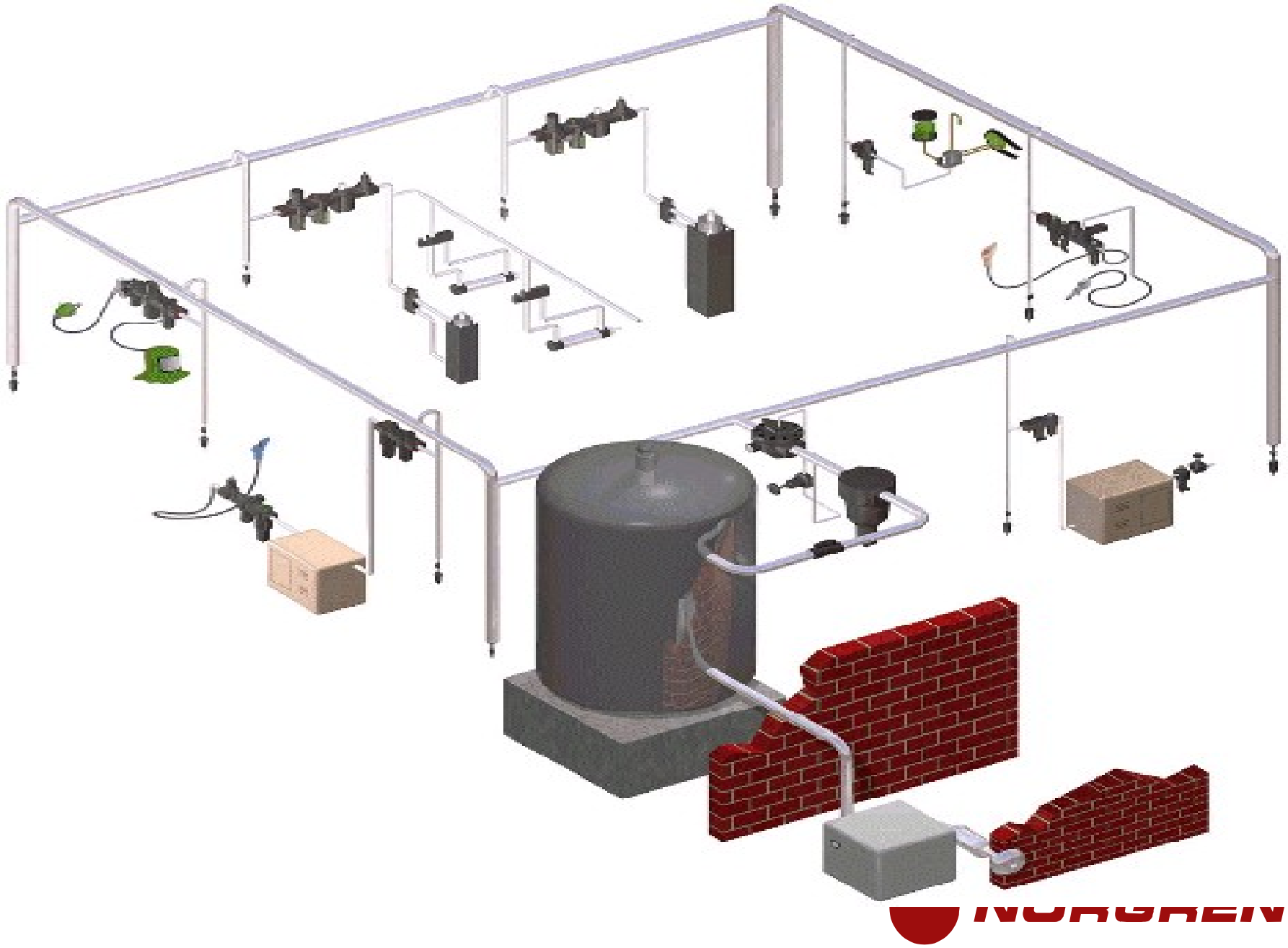
Why Filter Compressed Air?

Oil, dust, dirt and water contaminate compressed air systems*. Contaminants can *plug orifices wear out seals, erode system components*, reduce the efficiency of air-operated tools, damage finished products and otherwise contribute to product rejects *The best defense against oil and dirt is effective compressed air filters.

Figure CA1-1, Compressed Air

Air Quality

Quality	Applications
Plant Air	Air tools, general plant air
Instrument Air	Laboratories, paint spraying, powder coating, climate control
Process Air	Food and pharmaceutical process air, electronics
Breathing Air	Hospital air systems, diving tank refill stations, respirators for cleaning and/or grit blasting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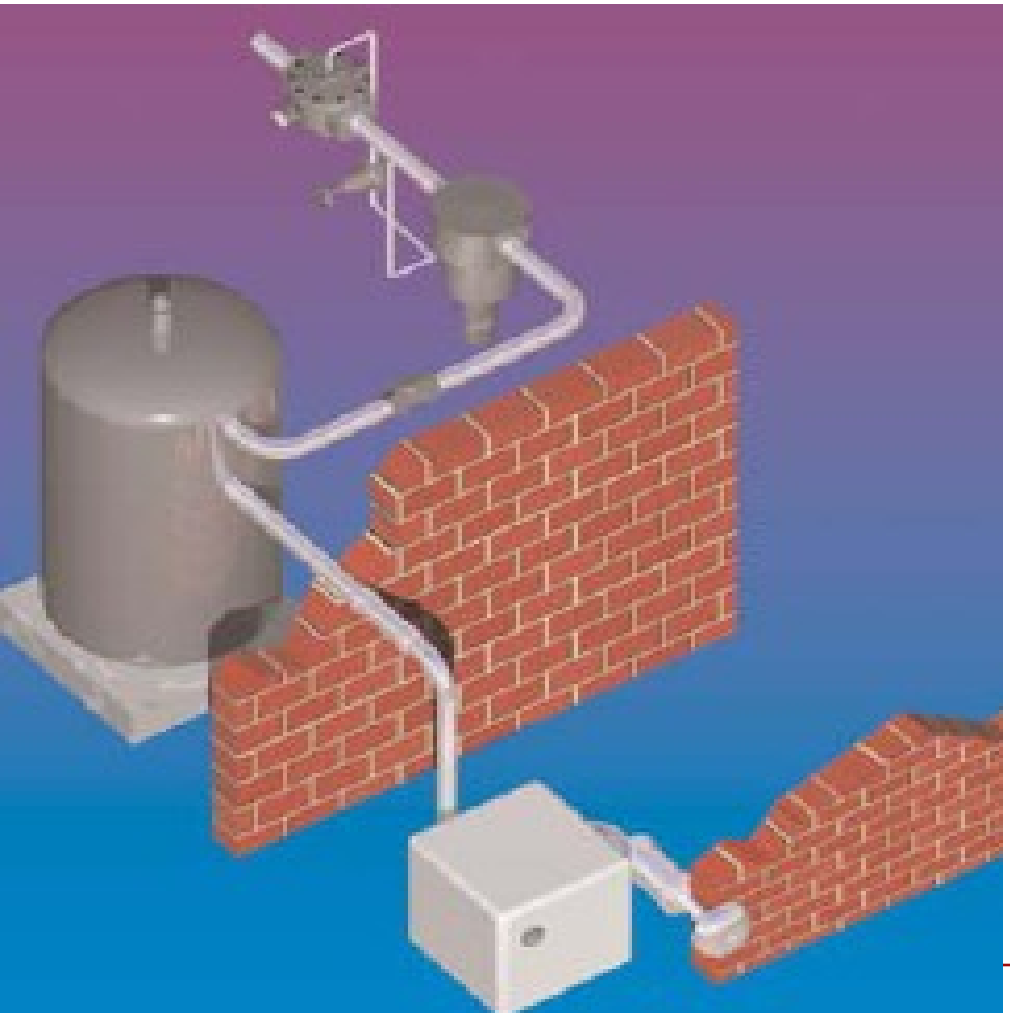
REMOVING CONTAMINANTS

The air produced by a compressor is hot, wet and dirty. The first step in good air preparation is to filter out these contaminants. This section considers the removal of liquid water, water vapor, solid particles and finally oil.



LIQUID WATER

In compressed air systems water vapor exists as a contaminant originating at the compressor outlet in vapor form, but as the air cools, it will exist as both liquid and vapor.

Most liquid water will be present when the temperature is lowest and the pressure is highest and removal at this point will achieve the highest efficiency.

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Types of compressed air inlet filters

Compressor Intake Filter

The first line of defense is the intake air filter, which reduces the bulk contaminant load protecting the compressor from dirt and solids. Generally, these are cartridge type filters with a greater than 98% air efficiency rating at 10µm. There has been a recent move to 3µm filtration. Over 80% of the contaminants challenging an intake filter are less than 2 um and therefore the majority of these contaminants enter the compressed air system with the intake air. Other compressed air filters are available to remove particulate contaminants down to 0.3 um and to remove chemical contaminants.

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Typical compressor inlet filter

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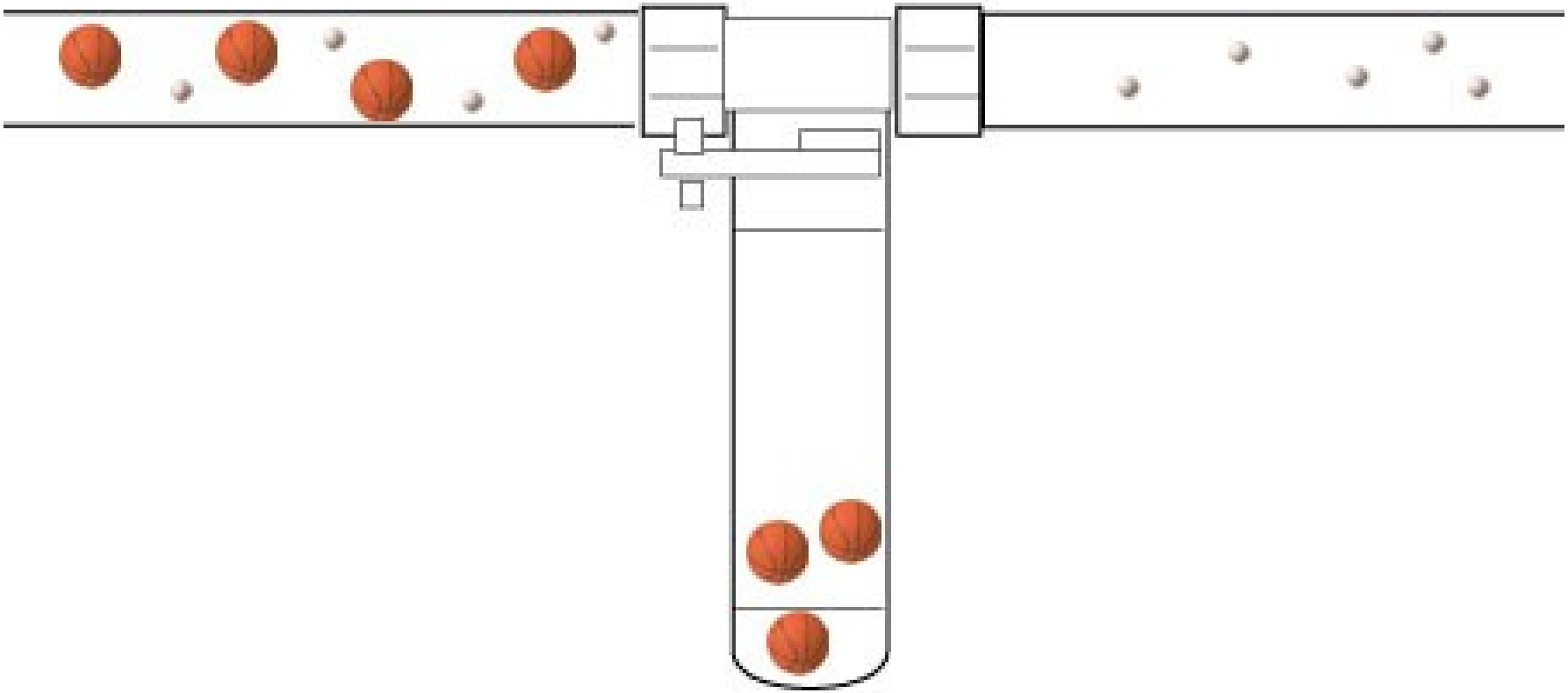
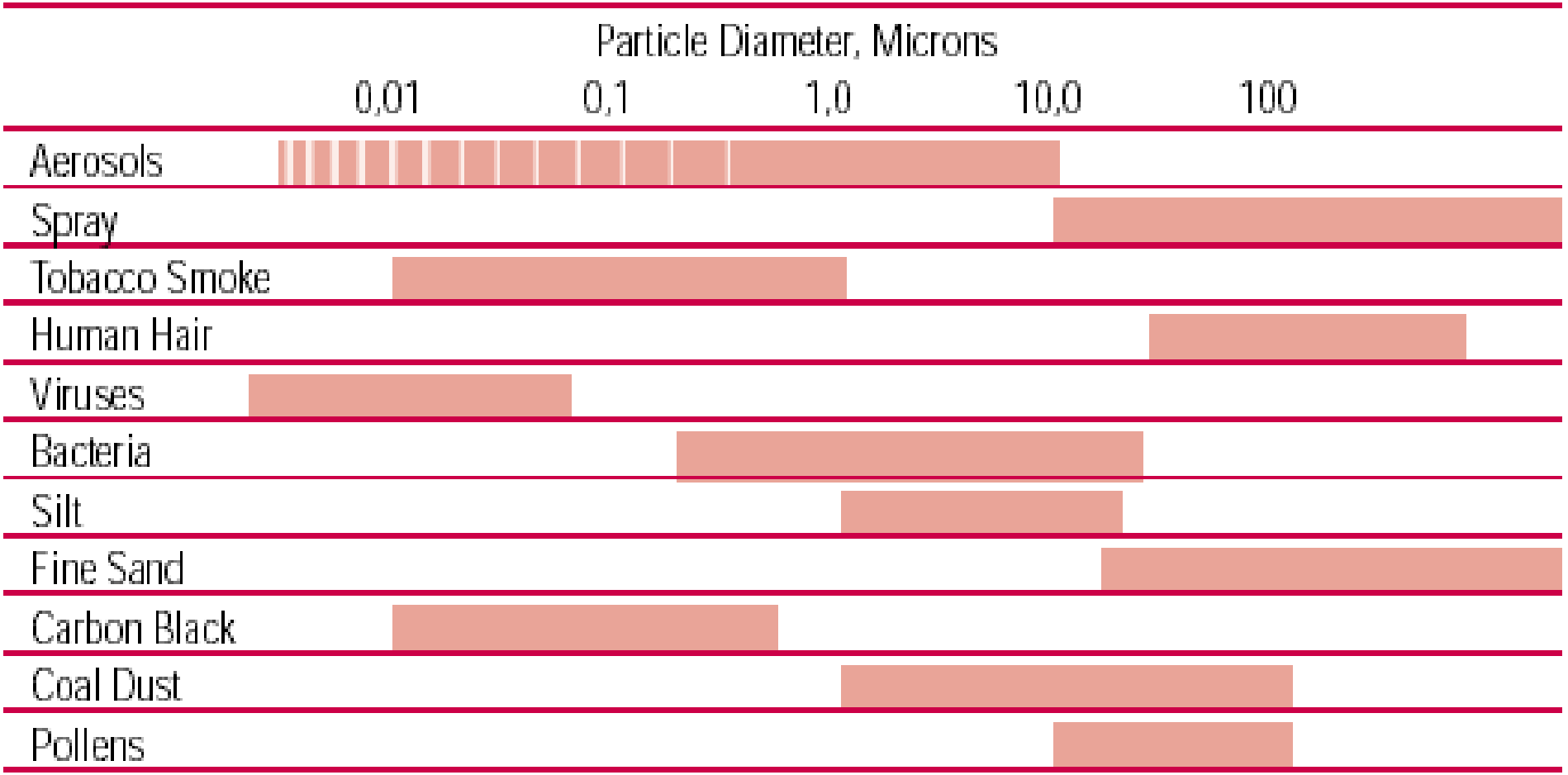
In terms of particle size, contaminants in a typical compressed air system range from 10 microns to 0.01 micron. A micron (or micrometer) is one-millionth of a meter or approximately 0.00004 inch.

If a 5-micron particle were represented by a basketball, then on the same scale, a 0.5-micron particle would be the size of a golf ball. This size difference (golf ball vs. basketball) explains why filters designed to remove particles 5 microns in diameter cannot take out oil mist at 0.5 micron and smaller.

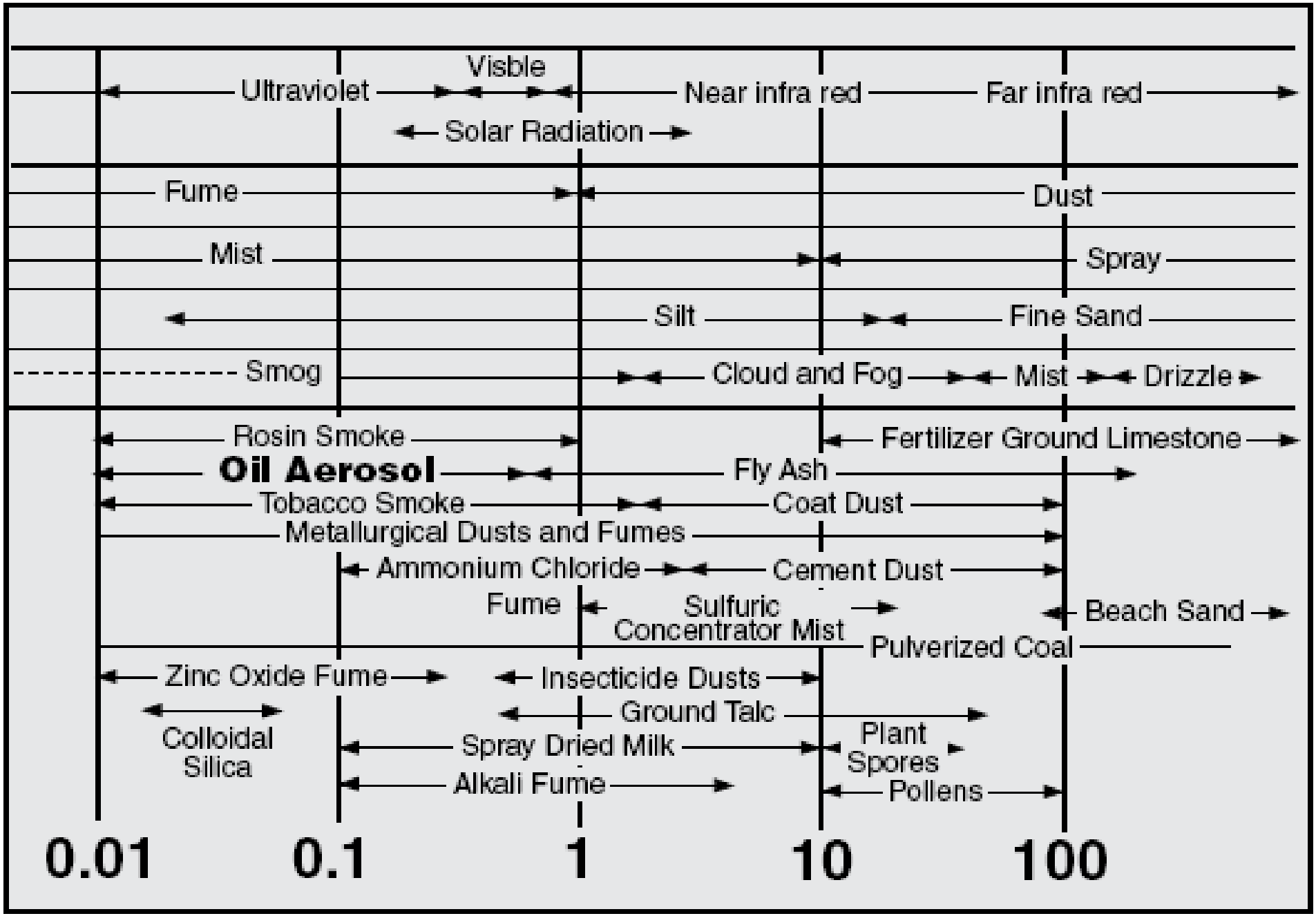


PARTICLE SIZES

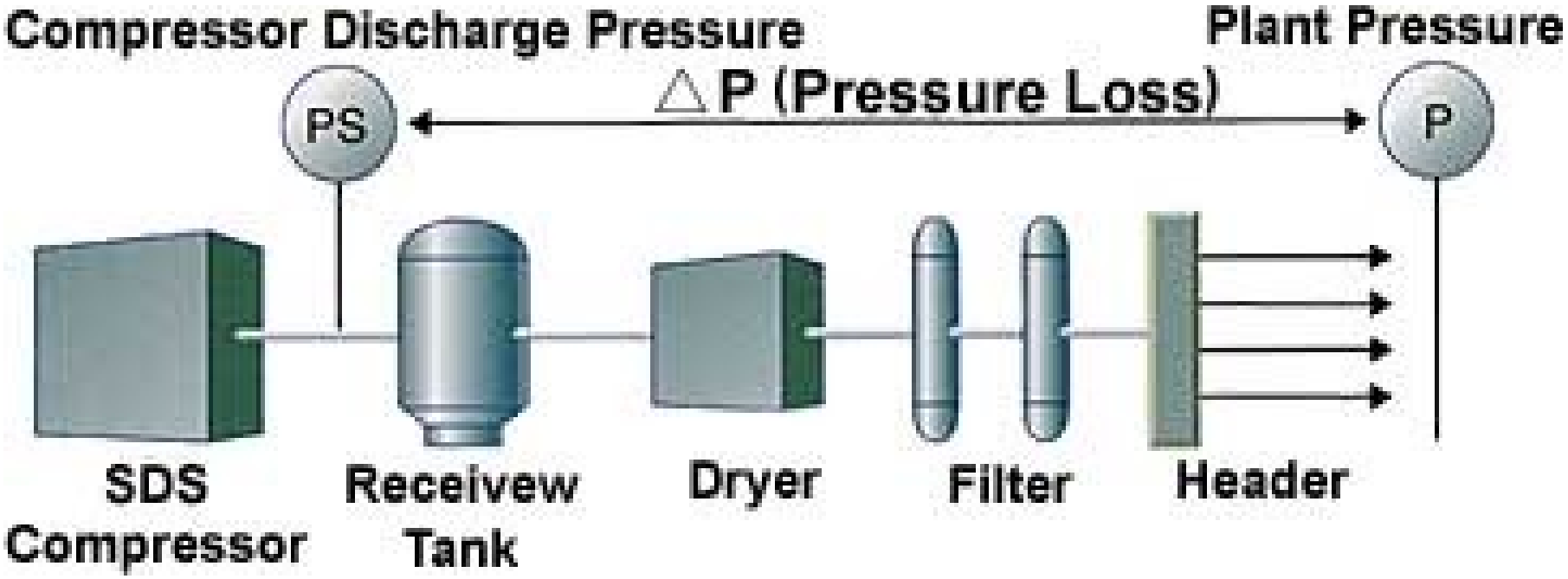
Figure 12. PARTICLE SIZES



Pollution Size Chart



Distribution pressure drop points



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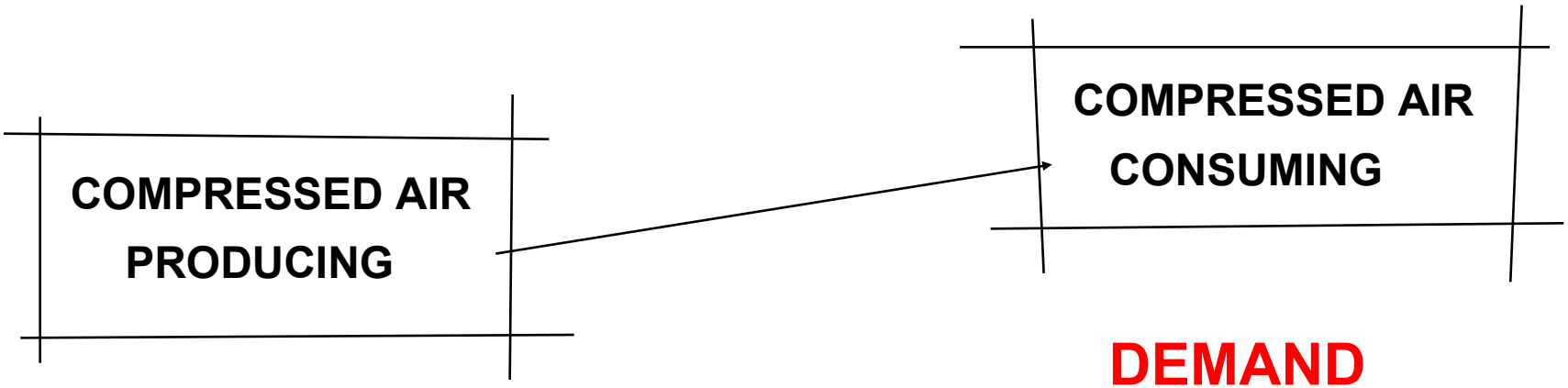
YOUR COMPRESSED AIR FACILITY



SUPPLY

DEMAND

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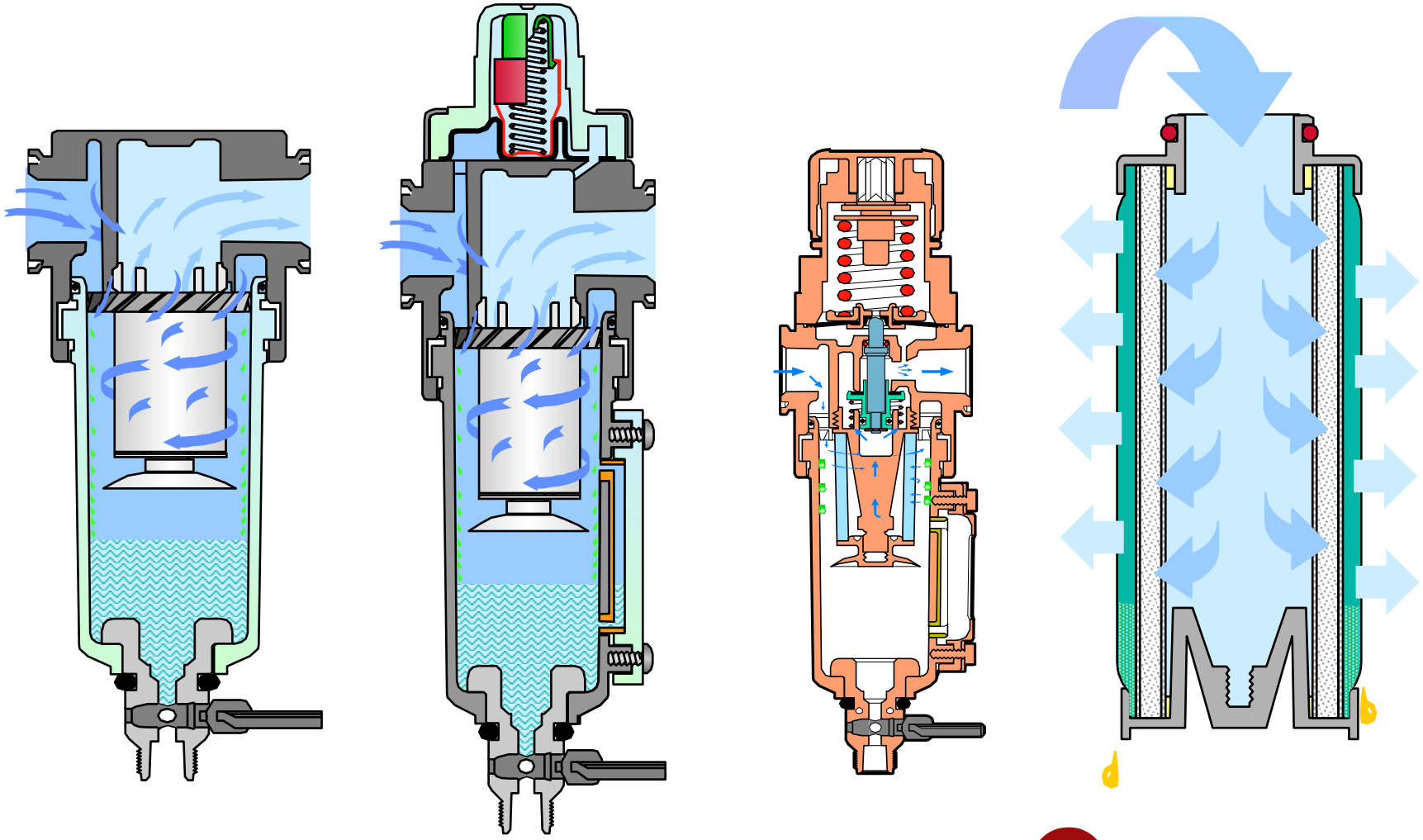
Filters in general



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Filtration Mechanisms

What makes a filter work? How do filters go about doing their job? By what principles do they operate?

Technically speaking, filters use the mechanisms of interception, inertial impaction, diffusion and adsorption. Each mechanism is effective in removing certain contaminants and certain particle sizes.

There are at least seven mechanisms by which a filter can capture particles. All of these mechanisms are at work in a filter at any given time to varying degrees and may change as operating conditions change. The seven mechanisms of particle capture are listed below:

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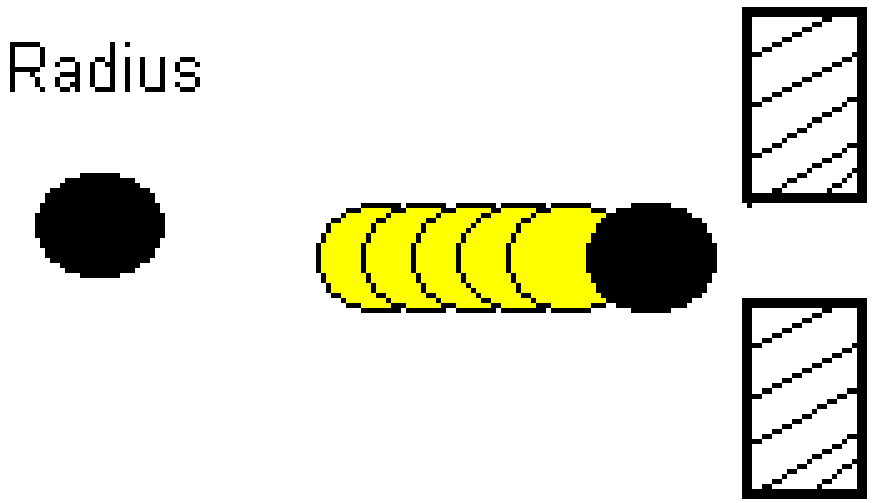
Direct Interception

Direct interception is usually the governing mechanism in liquid filtration. Interception of a particle occurs by this method when a particle approaches a media obstruction a distance equal to or less than the particle radius. In essence, if the particle "runs into" a physical barrier, it becomes captured.



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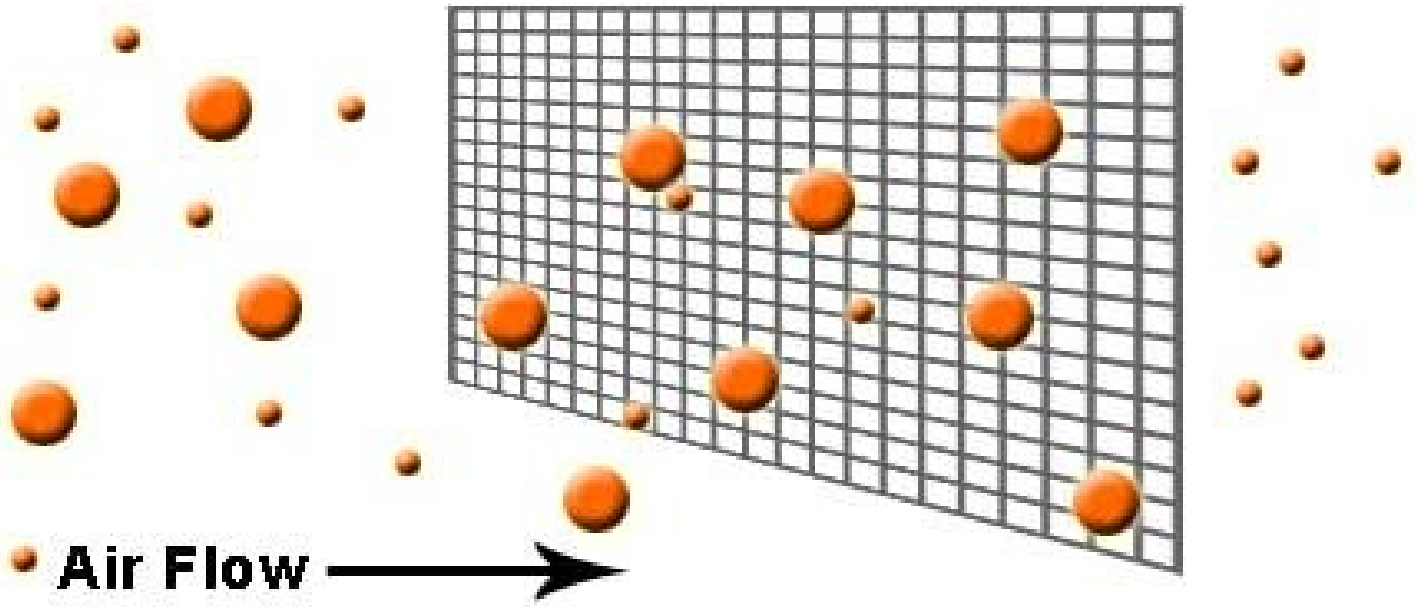
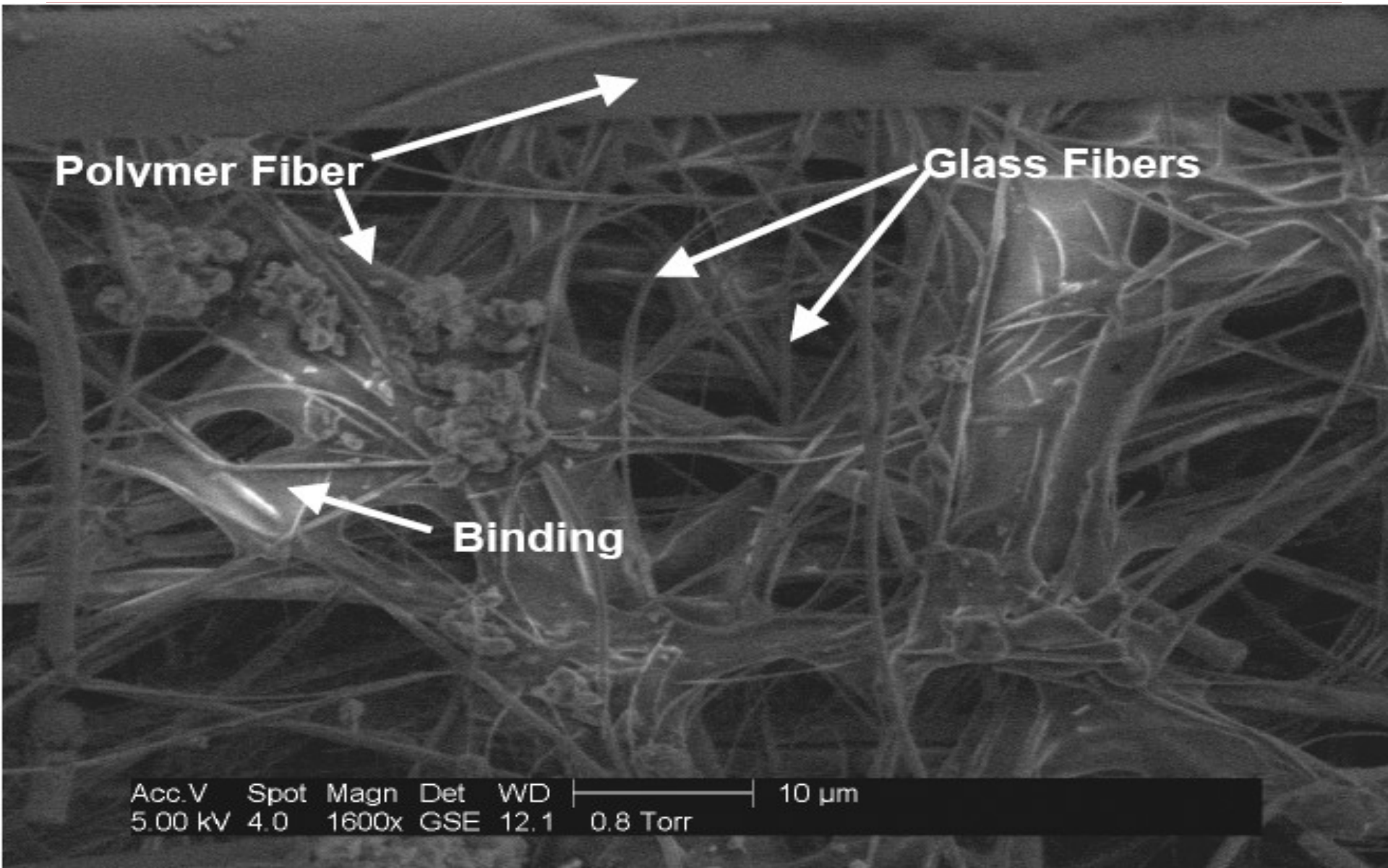
Direct Interception (particulate filters)

Interception, or mechanical separation, is the easiest filtration mechanism to envision. A moving particle is blocked when it encounters a passageway or hole smaller than itself. The larger the particle relative to the hole size, the greater the chance of interception.

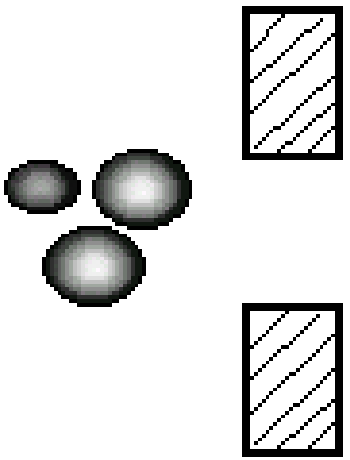


Element designs



Bridging

One single particle may be too small to be directly intercepted or blocked by the filter medium. However, two particles hitting the obstruction at the same time may stick together and be deposited. Particles form a bridge across a pore by hitting the pore simultaneously, or by adhering to each other earlier in the process and then becoming deposited. Bridged particles may not clog the opening completely, thus creating a smaller pore that is more difficult to pass through. The gradual accumulation of particles on the filter medium is known as the formation of a filter cake. This cake creates a finer matrix for subsequent interception.



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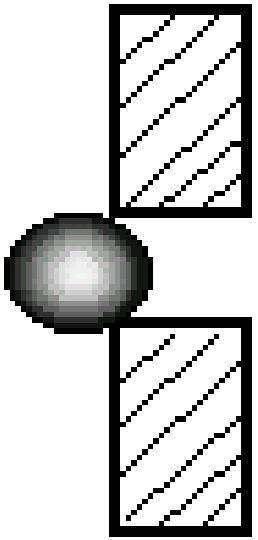
Sieving

Similar to bridging, sieving is a specialized case of direct interception. Sieving occurs when the opening or pore in the medium is more constrictive than the diameter of the particle. The particle is simply too large to pass through the pore. Sieving may occur on the surface of the filter or through the pore. Sieving may occur on the surface of the filter or throughout the depth of the medium.



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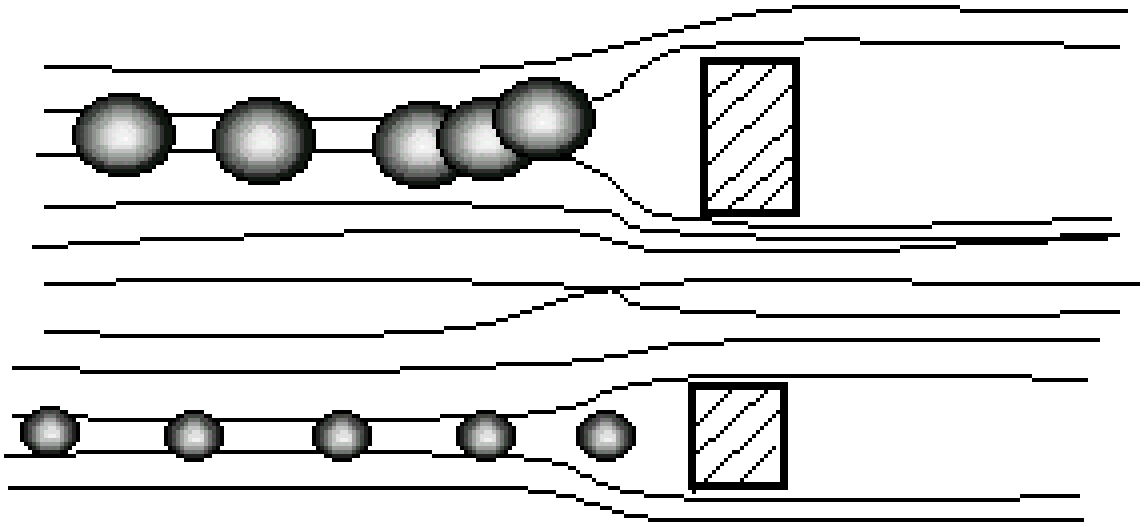
Inertial Impaction

Inertial impaction is based on the scientific principle of inertia, stating that a moving object will continue to move in a straight line unless acted on by an outside force. As particles flow through a filter, they may encounter an obstruction and become captured while the fluid flows around the barrier. Due to the inertia of the particle, it continues to move in a straight line and becomes impacted. Fluid viscosity also greatly affects inertial impaction.



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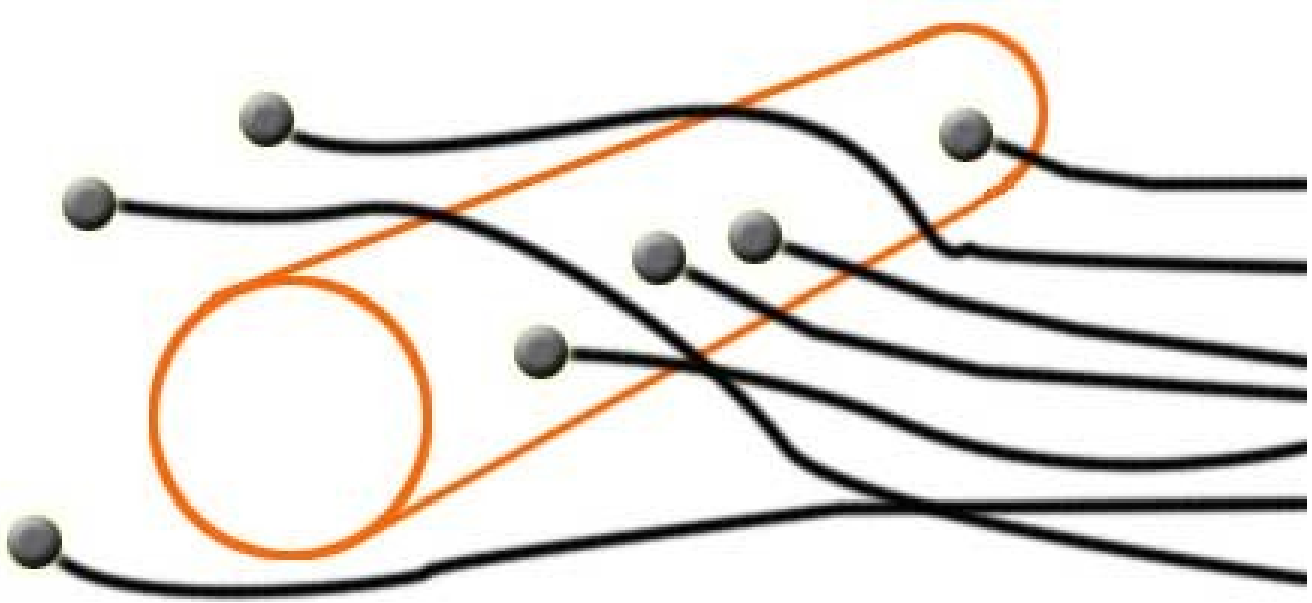
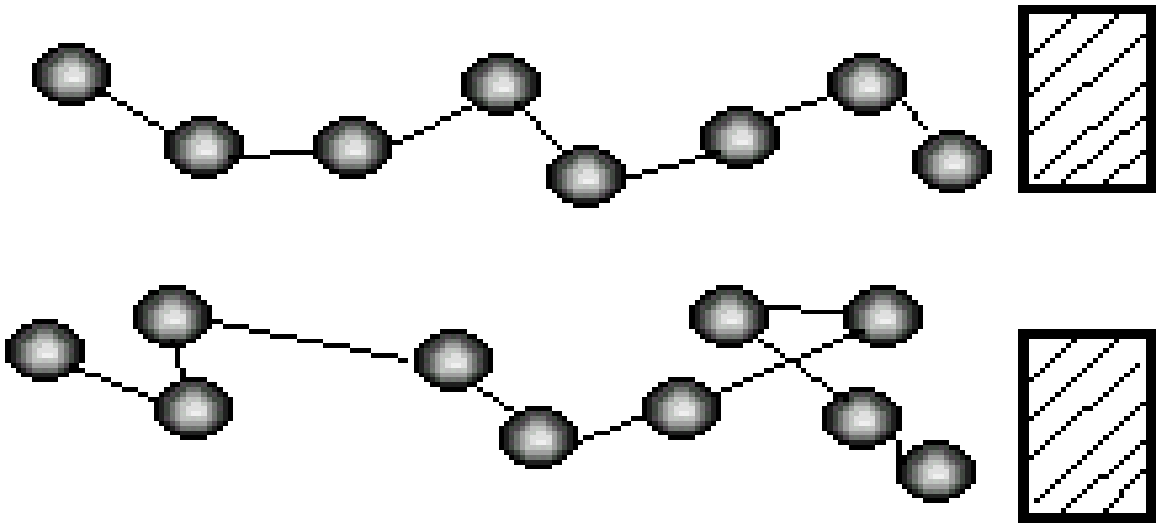
Inertial impaction, also referred to as impingement, occurs as the air-stream passes through a random network of fibers. Some particles will impact onto the filter medium and be caught due to their inertia driving them into the filter media. The compressed air-stream, because of its relatively low density and inertia, changes direction and flows around the fibers. Particles in the size range of 0.5 micron and larger, however, because of their higher density and inertia, randomly collide with the fibers. Hence, inertial impaction works to trap a high percentage of particles not trapped by interception.



Diffusion Interception

The mechanism of diffusion interception is attributable to the fact that molecules are in constant random motion. This motion enhances the opportunity for a particle to become intercepted by the filter medium.

Diffusion interception is more prevalent in particles that are 0.1 to 0.3 microns in size, since small particles are most affected by molecular bombardment. Diffusion interception is primarily found in gases due to their inherently low viscosity and high degree of molecular mobility.



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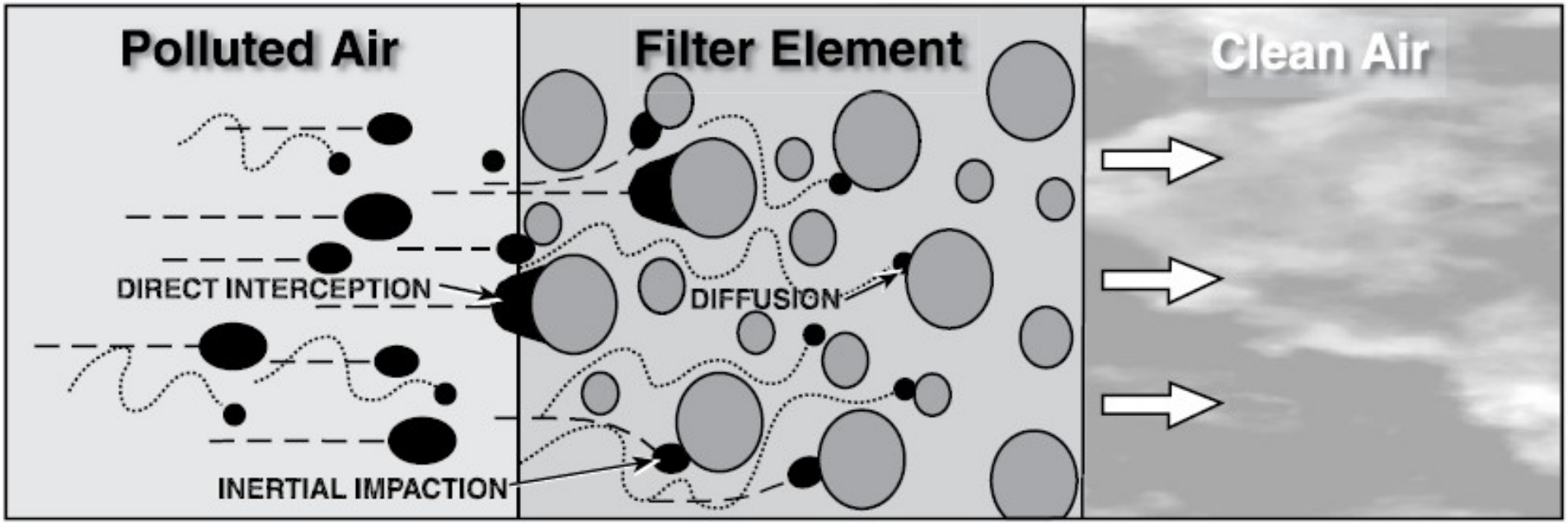
Diffusional interception

Extremely small particles will bounce around randomly in a gas stream as they strike liquid or gas molecules. This motion is called Brownian Motion and is more pronounced in gases. The random path of the particle increases the chance it will strike the compressed air filter and be captured.

Filter Technology – Mechanisms of Filtration



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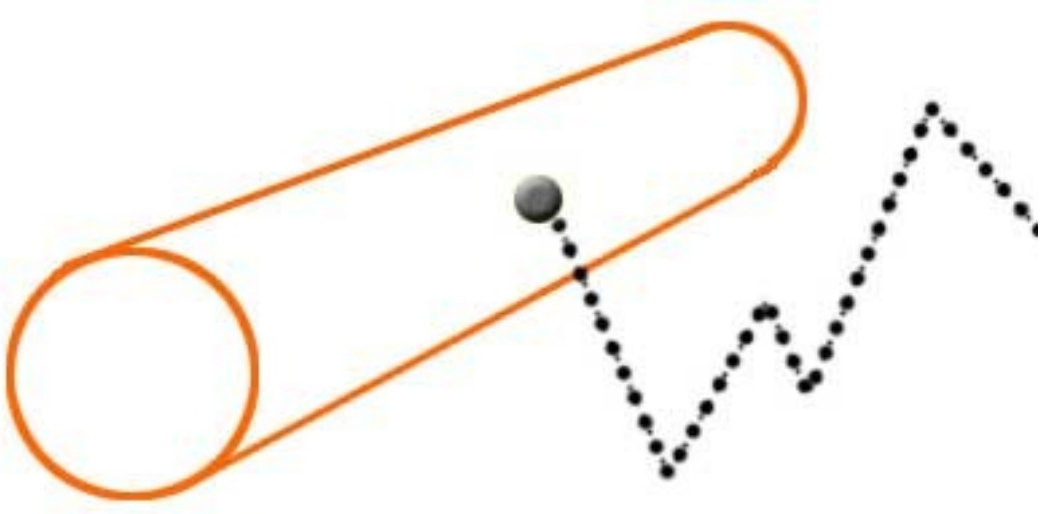
Diffusion

Diffusion refers to the random motion of small particles, also known as Brownian motion. This motion is caused by collisions with gas molecules, Particles in the size range of 0.1 micron and smaller do not tend to follow the air-stream.. The random path of the particle increases the chance it will strike the filter and be captured.



Electrokinetic Effects

Electrical charges may be present on the filter medium and / or on the particles. Particle deposition can occur due to attractive forces between charges or induced forces due to the proximity of the particle to the medium. Some manufacturers purposely alter the surface of the filter medium to enhance electrokinetic capture.

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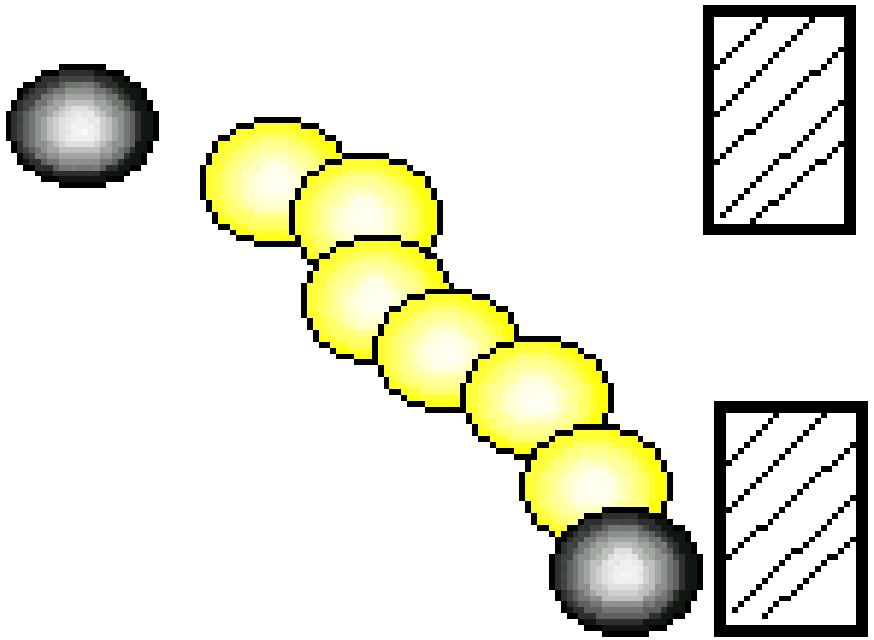
Gravitational Settling

Particles have mass and are therefore affected by gravity. It is possible that a particle may leave the fluid streamlines and settle in the same fashion as sediment in a settling tank. Particles may be deposited within a filter medium or in the up-stream chamber of a filter housing.



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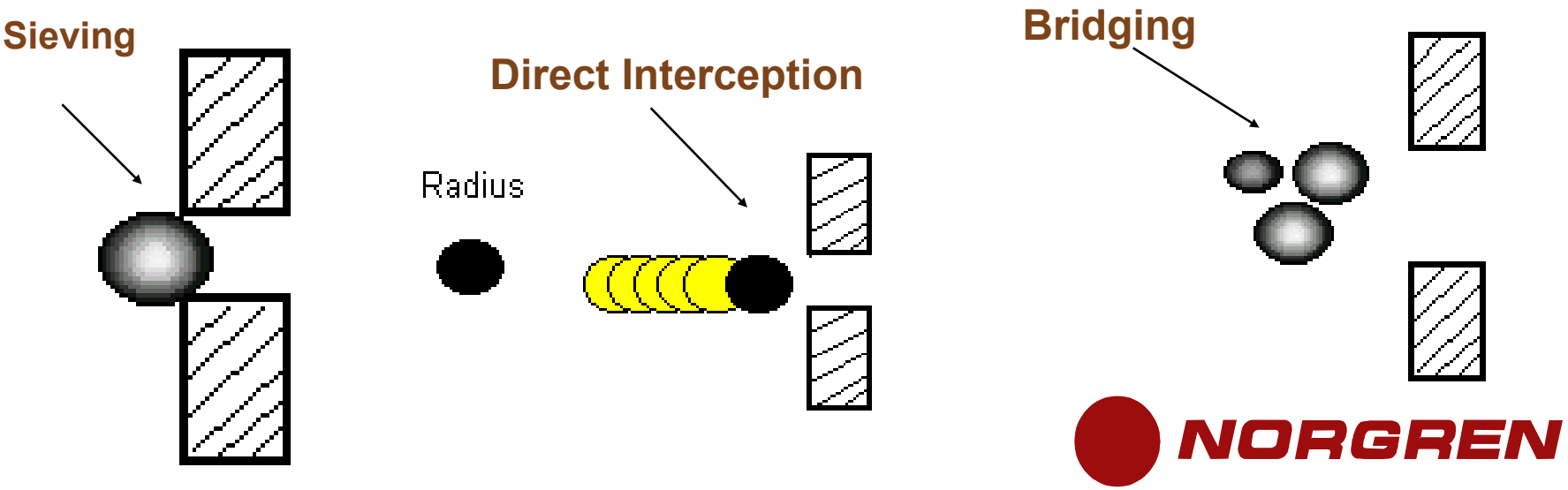
Mechanical Retention

Mechanical retention occurs when a particle is mechanically restricted from passing through the filter medium. Direct interception, sieving, and bridging are mechanisms of capture that facilitate mechanical retention. Of these three methods of capture, sieving is the most dependable under normal forward flow conditions.



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Adsorptive Retention

Adsorptive retention refers to the adherence of a particle to the filter medium due to interactions between the particle and the surface of the medium. The particle "sticks" to the filter. Phenomena behind this adsorptive affect include electrical and hydrophobic interactions. Smaller particles adsorb more strongly than larger particles. The tendency of particles to adsorb, however, is very condition dependent; a particle that is adsorbed can be desorbed. Adsorptive retention predominates for particles captured by inertial impaction, diffusion interception, and electrokinetic attraction.

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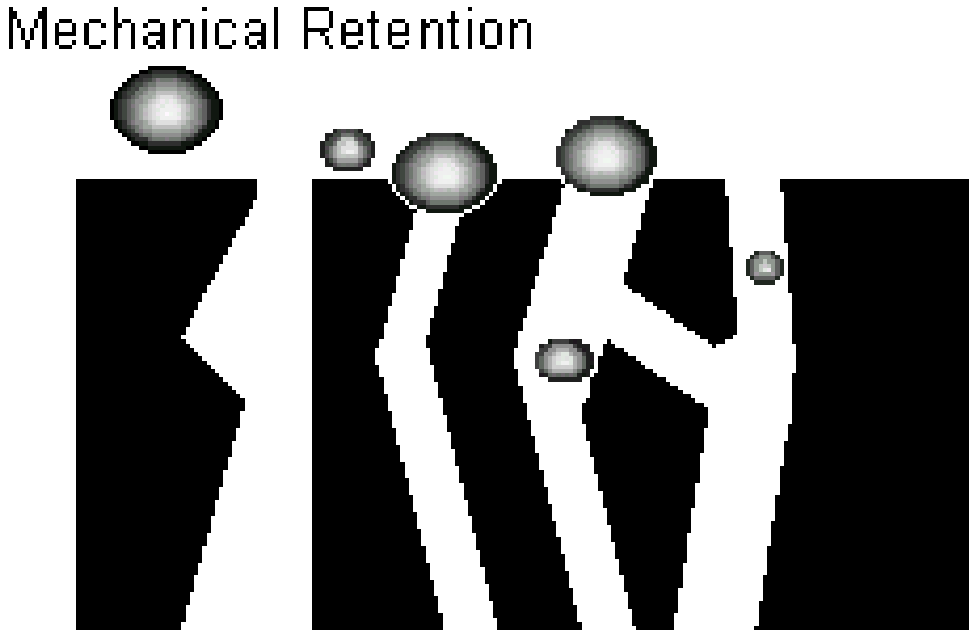
Surface vs. Depth Filtration

The terms “surface filtration” and “depth filtration” describe parameters of the particle size / pore size relationship present during the filtration process. Although filters are often generalized as being surface or depth filters, in reality, the label is inappropriate unless the particle size / pore size relationship is known.



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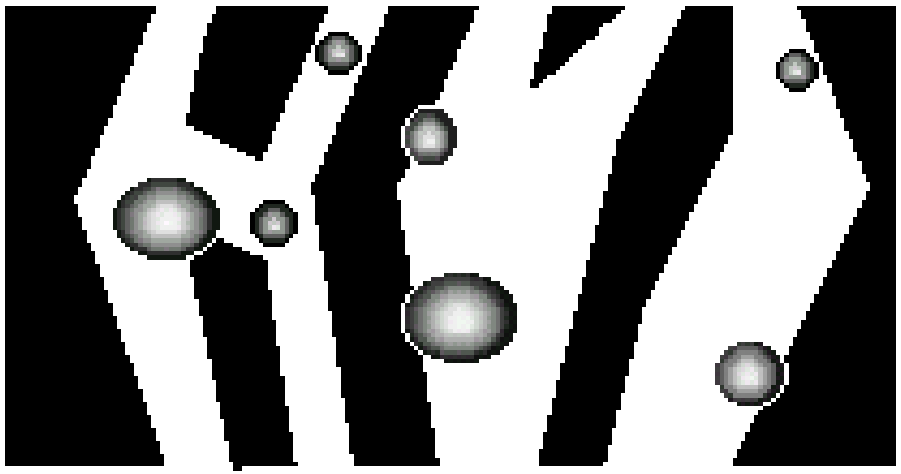
Surface Filtration

A true surface filter can be thought of as a screen that is challenged with particles that are too large to pass through its openings. The particles will collect on the surface, forming a filter cake. Retention will be absolute since no particles will be able to penetrate through the surface. This mechanism of capture is recognized as sieving. Note, however, that if the same screen was challenged with small enough particles, it would no longer capture all of the contaminant's at the surface. Hence, the process of surface filtration is strictly dependent upon the particle size / pore size relationship.

Adsorptive Retention



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Compressed air filter locations

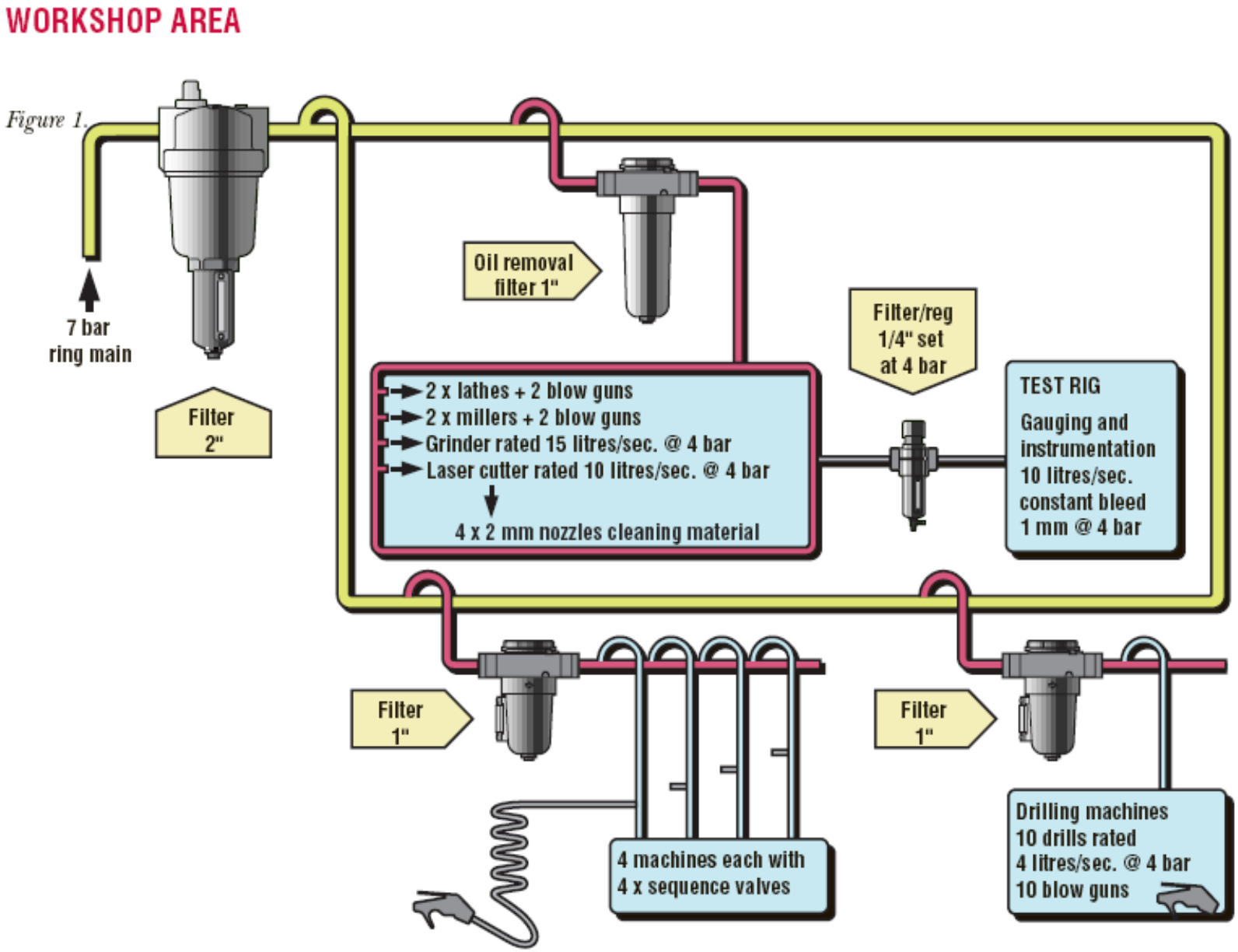
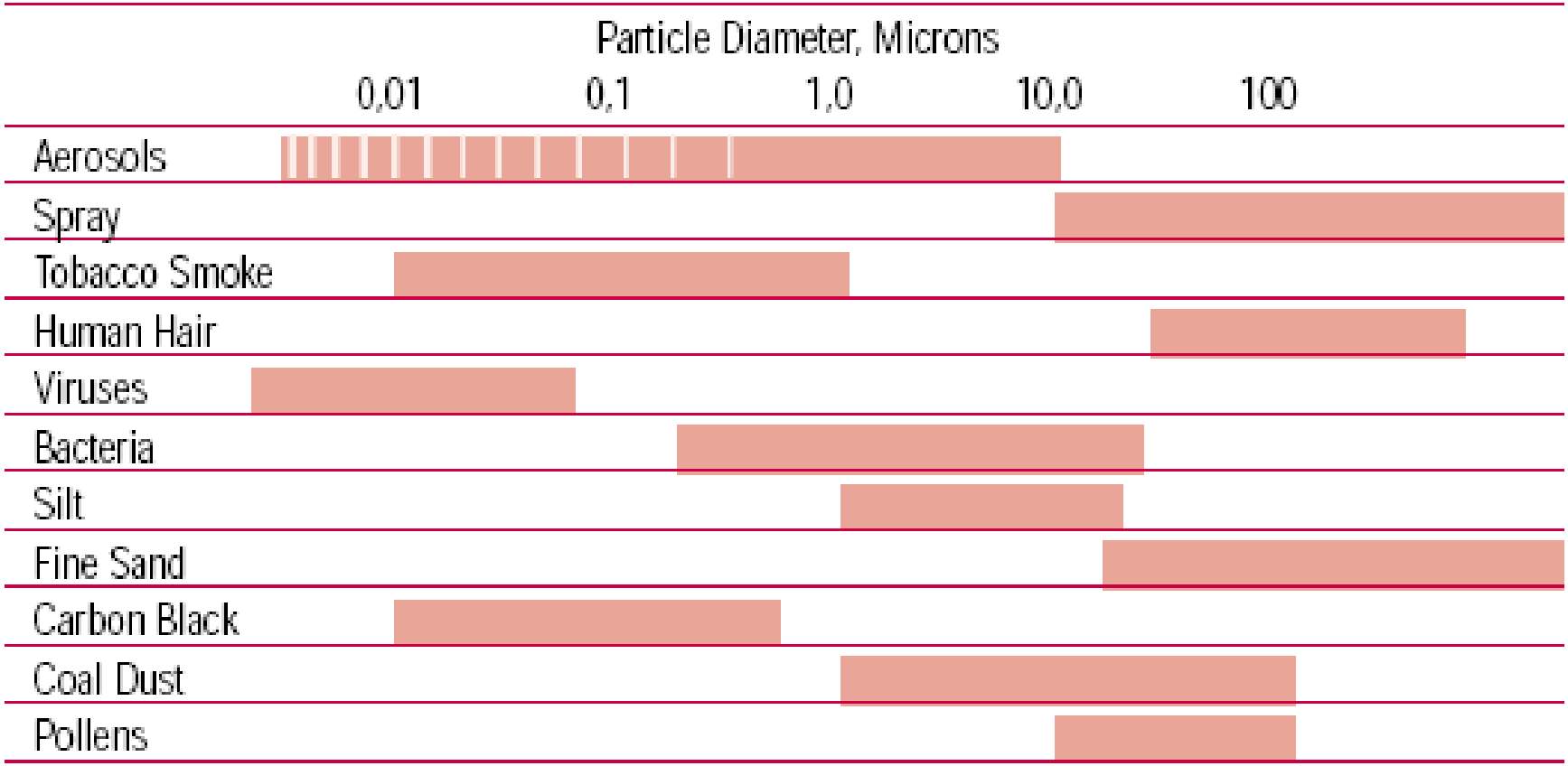


Figure 12. PARTICLE SIZES



CONTAMINANTS

Contaminants include:

Solids

Water

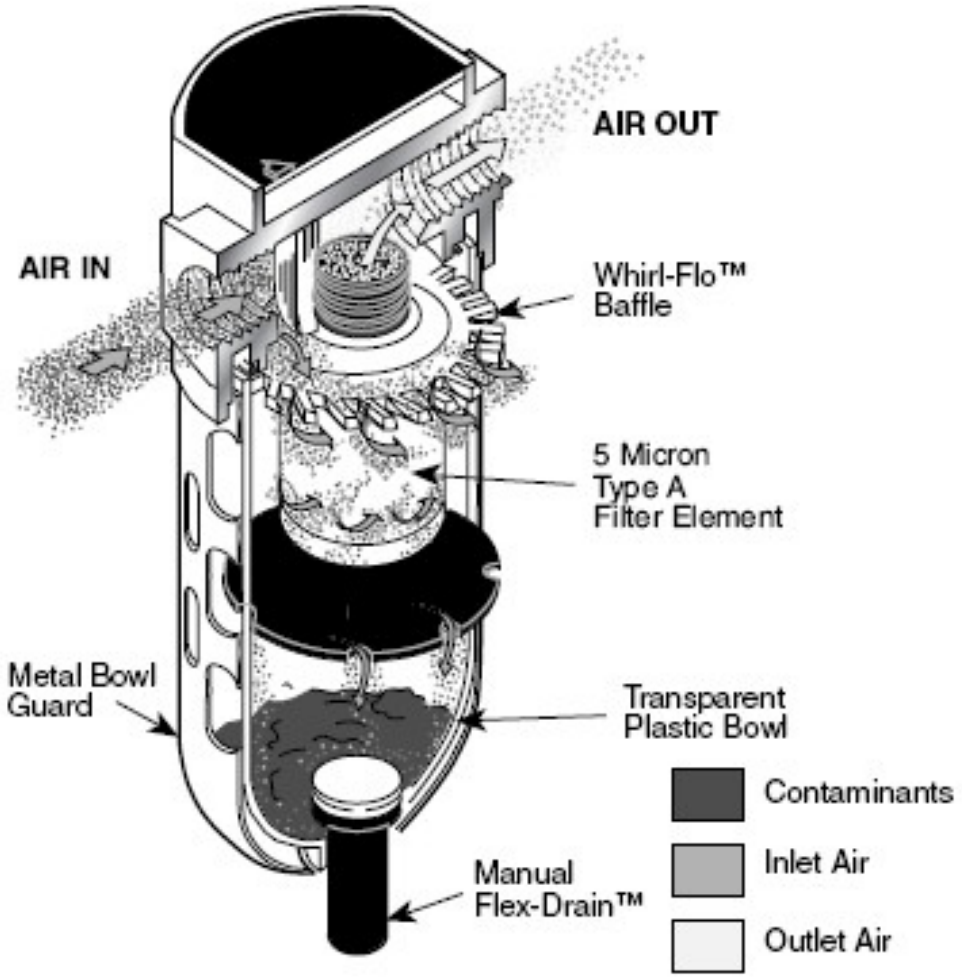
Oil in various forms

Oil comes from the air compressor, moisture comes from the cooling compressed air and dirt is present in the intake air. More contaminants are made as these contaminants damage pipe and compressed air components. In addition to hard particles, bacteria will grow and a sludge of oil, water, bacteria and hard particles forms.

PARTICULATE FILTER

For the removal of solid particle contaminants down to 5 microns and the separation of bulk liquids.

should also be used as a prefilter for the Coalescing (oil removal) filter.

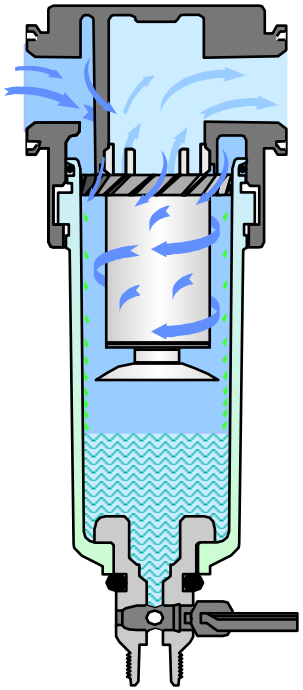


NORGREN

PARTICULATE FILTER

For SOLID CONTAMINANTS

F18 18 Series
General Purpose Filter
1 1/2″ and 2″ Port Sizes



F17 17 Series
General Purpose Filter
3/4″, 1″, 1 1/4″, 1 1/2″ Port Sizes

NORGREN

SOLID PARTICLES

EXCELON MODULAR SYSTEM

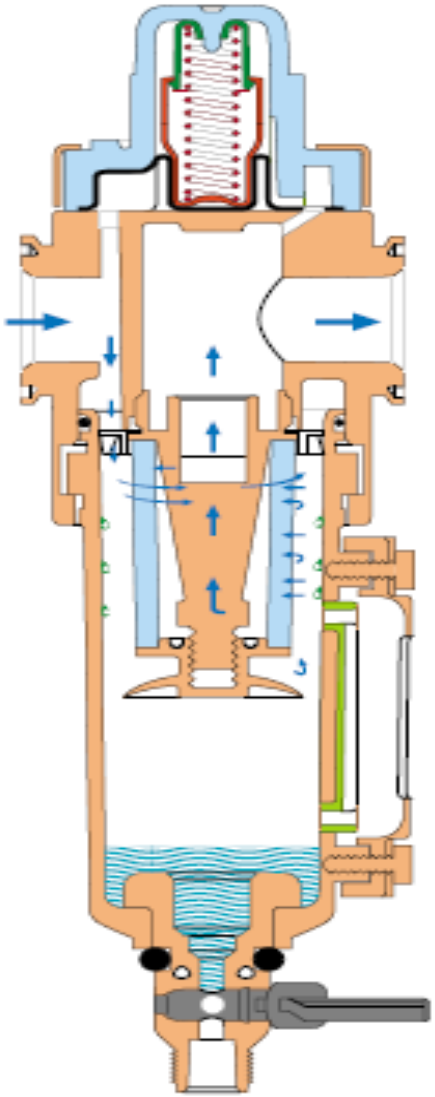
General purpose filters

F72G, F73G, F74G

G¼ to G¾

F72G F73G F74G

GENERAL PURPOSE FILTER



FILTER SERVICE INDICATOR

NORGREN

F17

17 Series
General Purpose Filter
3/4", 1", 1 1/4", 1 1/2" Port Sizes

- Protects air operated devices by removing liquid and solid contaminants from compressed air

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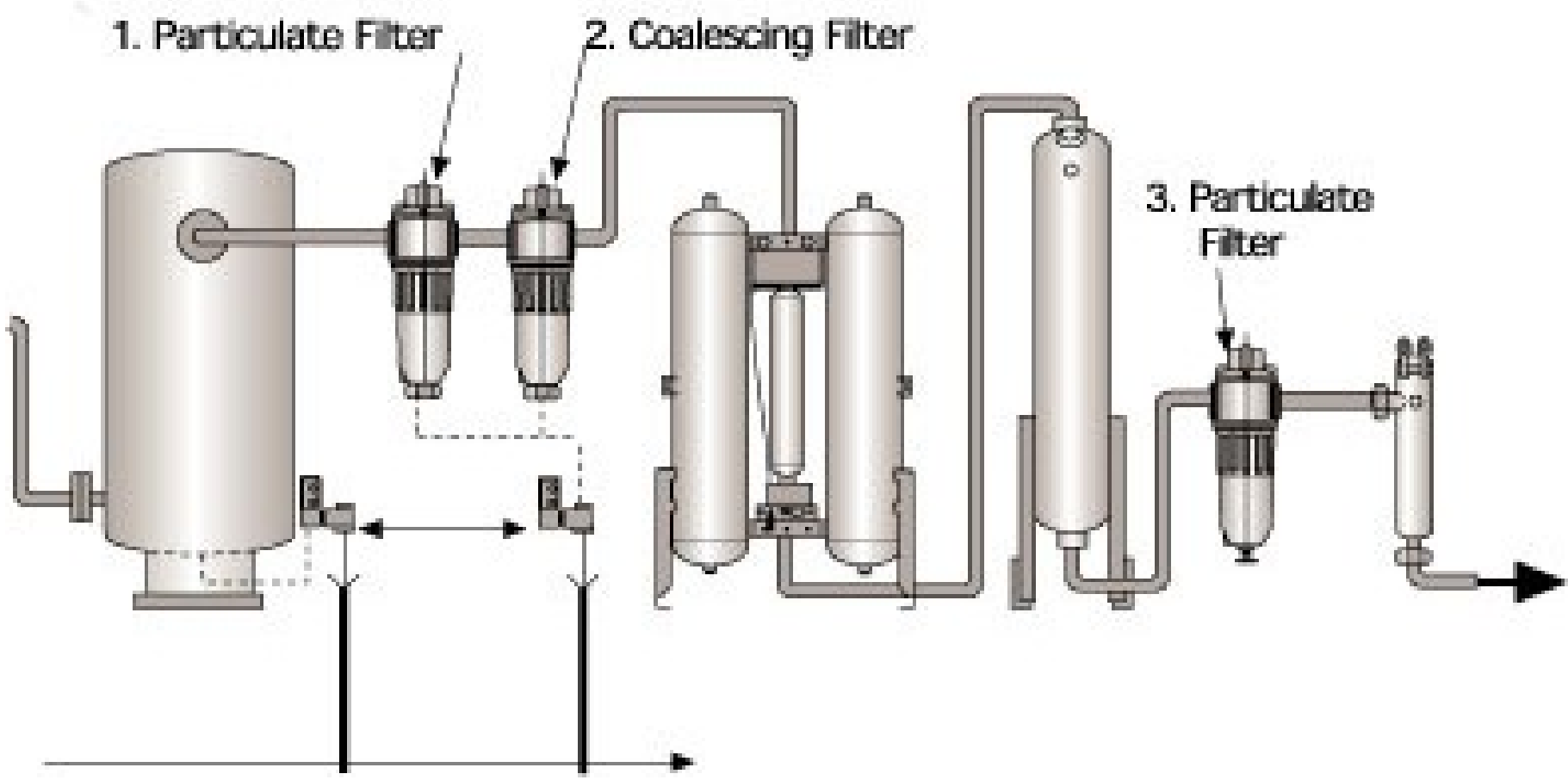
1. Particulate Filter
2. Coalescing Filter
3. Particulate Filter

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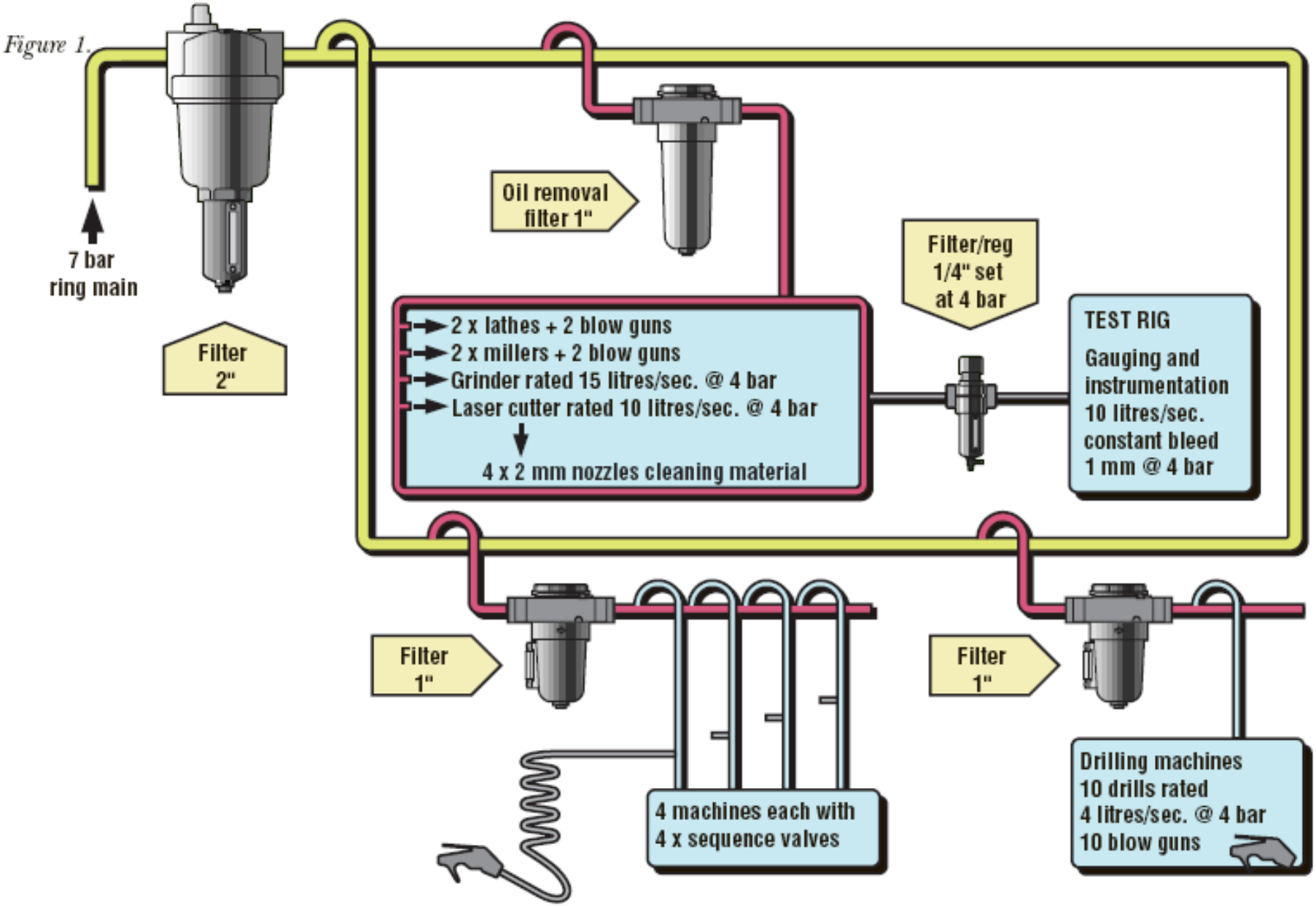
WORKSHOP AREA

KINETIC FLUIDTRONICS INCORPORATED

Figure 1.



Particulate filtration **is used to combat the destructive effects of solid contaminants in a compressed air system. Particulate filters down to 0.003µm protect air systems from contaminants. The smallest particle the human eye can see is 40µm.**

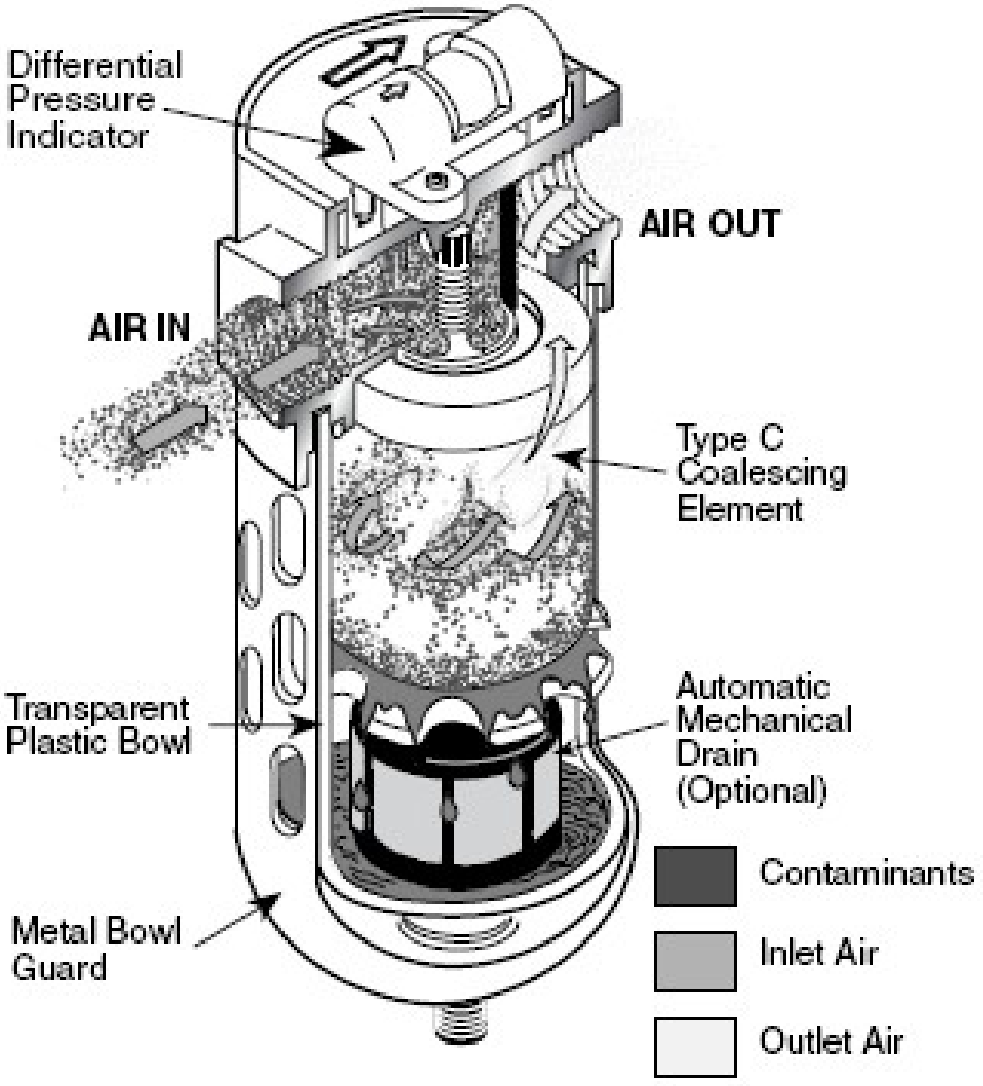
An additional effect of compressing air is aerosol and vapor concentration. Compressed air is saturated with water. Since the compressed air is heated during the compression process, an aftercooler is then used to remove the heat of compression. During this stage a significant quantity of aerosols and vapors are condensed into liquid at temperature.

LIQUID OIL

Oil mist particles have diameters in the range of 0.01 micron to 10.0 microns. Conventional air line filters remove only the larger particles. The smaller particles that pass through the filter eventually collide with one another and with confining surfaces, forming droplets large enough to settle out in the air line network as liquid oil. The formation of larger droplets from small particles is known as coalescence, and occurs more readily in regions of high turbulence where small oil particles are forcefully thrown against enclosing surfaces and against each other. This is why liquid oil is commonly found in orifices, pressure reducers and nozzles as well as in other areas of turbulence downstream of these devices.

COALESCING FILTER

(Oil Removal)

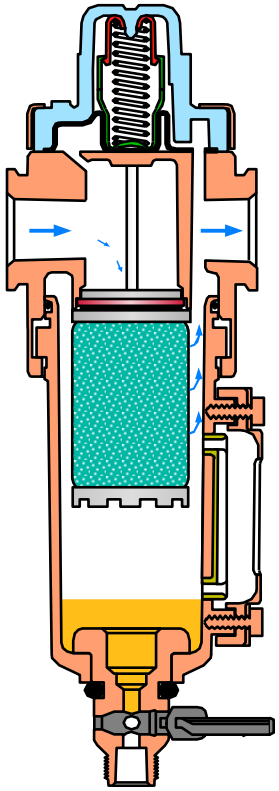


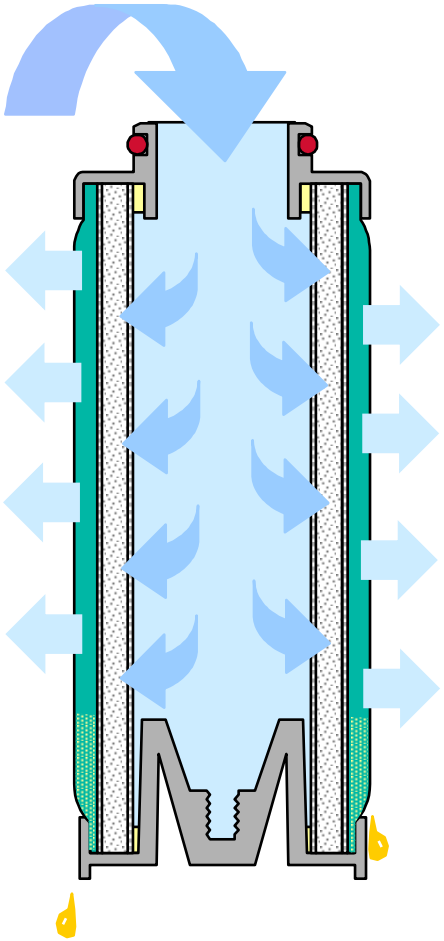
NORGREN

COALESCING FILTERS

Use to remove lubricant oil and MOISTURE

F46 Oil Removal Filter





17 Series
Oil Removal (Coalescing) Filter
3/4", 1", 1 1/4" Port Sizes

NORGREN

Coalescing exhaust silencers

Effectively reduces noise emission of multi-valve and cylinder systems

Removes oil mist and sub-micron particles from exhaust air

NORGREN

F46 Oil Removal Filter

17 Series
Oil Removal (Coalescing) Filter
3/4", 1", 1 1/4" Port Sizes

- **High efficiency oil and particle removal**
- **Standard service indicator turns from green t when the filter element needs to be replaced**

Install an F17 filter with a 5 µm filter element upstream of F46 filter for maximum service life.

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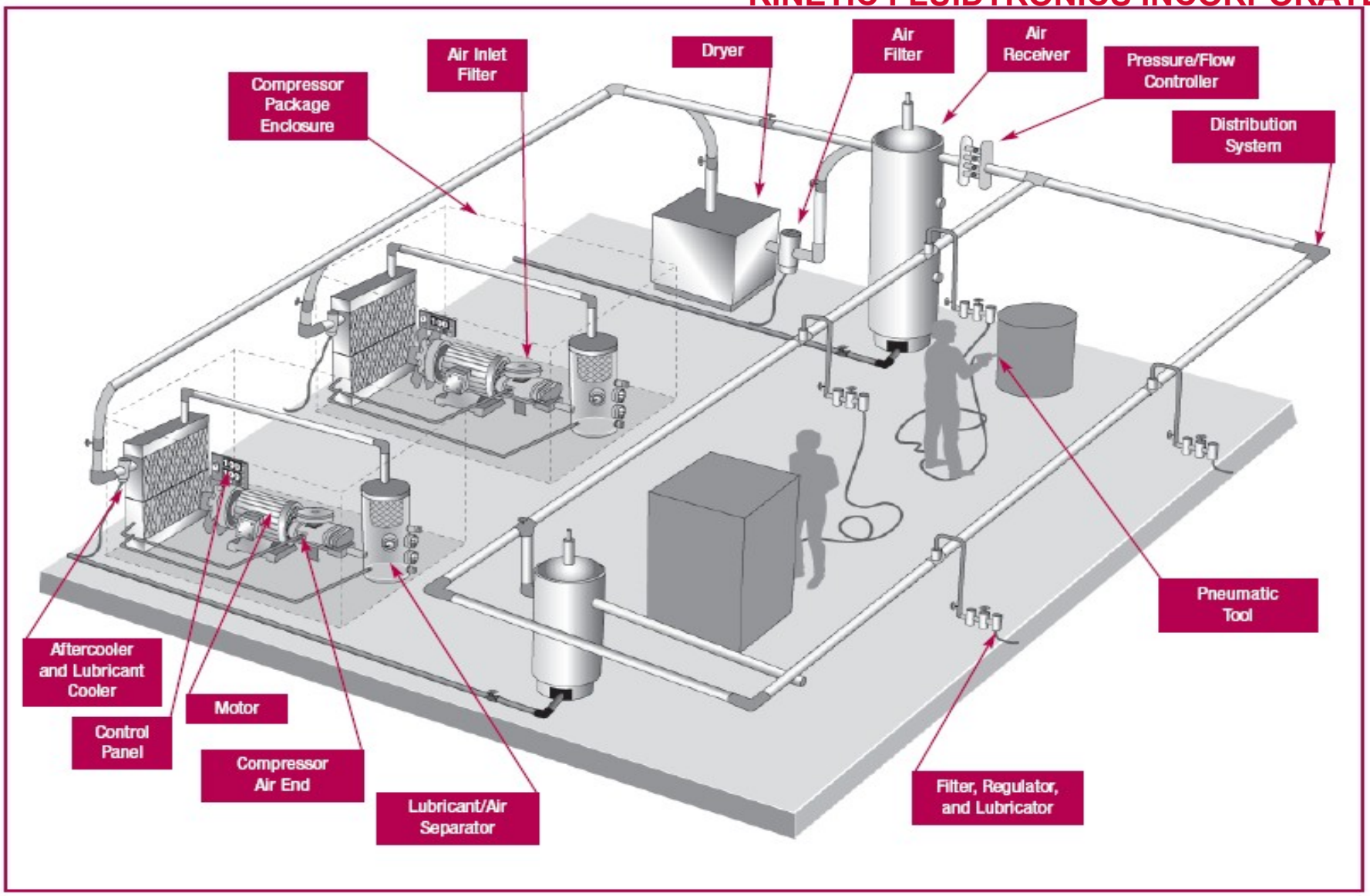


Figure 1.1 Components of a Typical Industrial Compressed Air System.

Coarse Coalescer Filter

A coarse coalescing filter separates large water and oil droplets from the compressed air stream before the coalescing filter. The coarse coalescer also removes large solids. Typically, the coarse coalescer is a 3µm coalescer. By using staged filtration you protect the more expensive coalescer filter, making it last longer online. The idea is to change the less expensive coarse coalescing filter more often to reduce overall filtration cost. A coarse coalescer filter is optional equipment. Not all air systems utilize it.

What Causes Pressure Drop?

Any type of obstruction, restriction, or roughness in the system will cause resistance to air flow and cause pressure drop. In the distribution system, the highest pressure drops usually are found at the points-of-use, including undersized or leaking hoses, tubes, disconnects, filters, regulators and lubricators (FRLs). On the supply side of the system, air/lubricant separators, aftercoolers, moisture separators, dryers and filters can be the main items causing significant pressure drops.

Leakage can be estimated in systems with other control strategies if there is a pressure gauge downstream of the receiver. This method requires an estimate of total system volume, including any downstream secondary air receivers, air mains, and piping (V, in cubic feet). The system is started and brought to the normal operating pressure (P_1). Measurements should then be taken of the time (T) it takes for the system to drop to a lower pressure (P_2), which should be a point equal to about one-half the operating pressure.

Leakage can be calculated as follows:

$$\text{Leakage (cfm free air)} = (V \times (P_1 - P_2)/T \times 14.7) \times 1.25$$

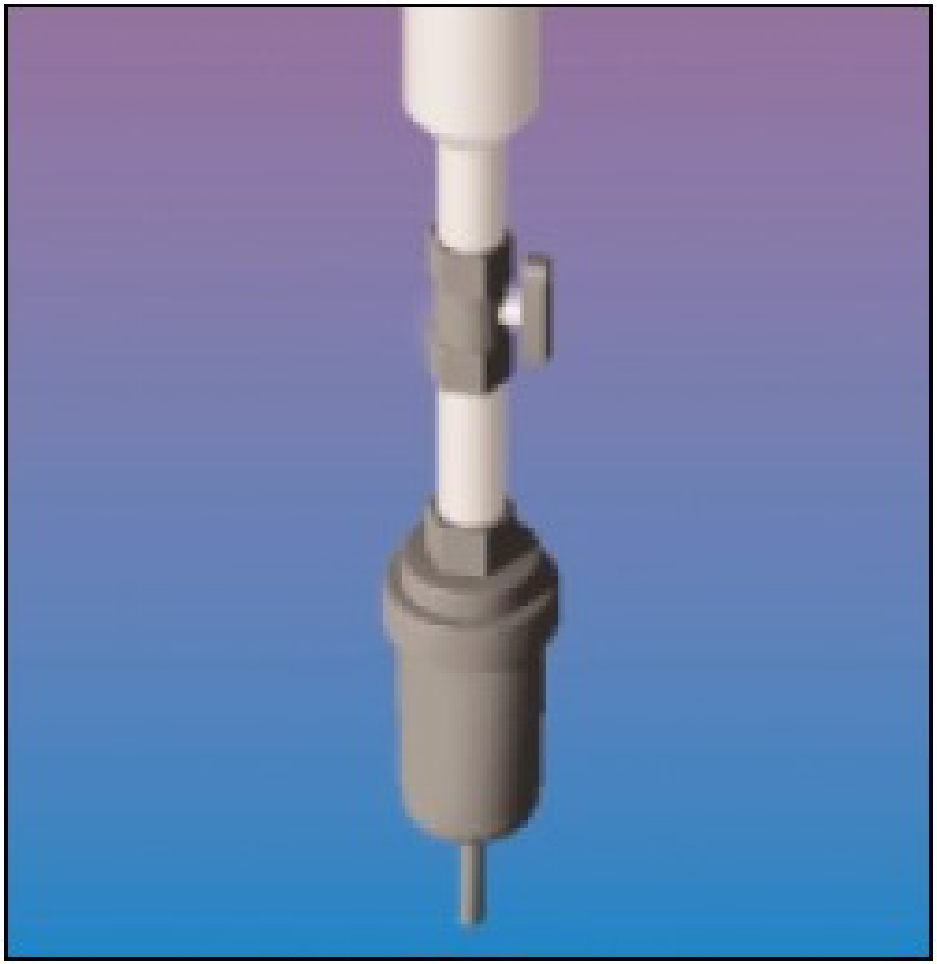
where: V is in cubic feet
P_1 and P_2 are in psig
T is in minutes

The 1.25 multiplier corrects leakage to normal system pressure, allowing for reduced leakage with falling system pressure. Again, leakage of greater than 10 percent indicates that the system can likely be improved. These tests should be carried out on a regular basis as part of a leak detection and repair program.

At discharge pressures of 100 psig, most water-cooled aftercoolers will need about 3 gpm per 100 CFM of compressed air.

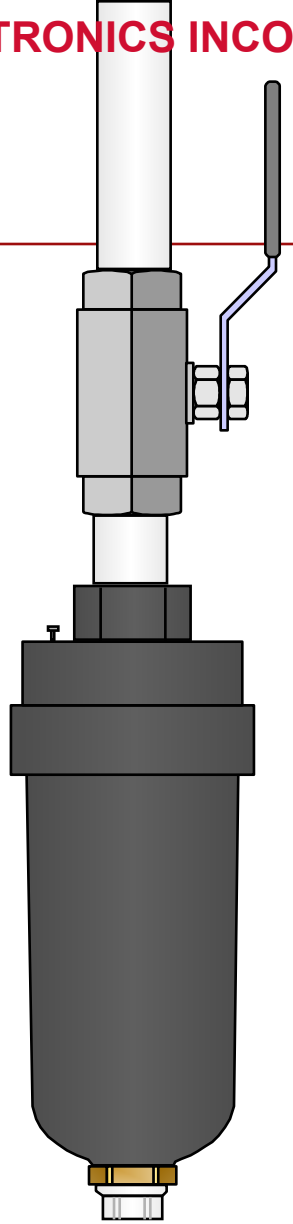
The water vapor content at 100°F (37.78°C) of saturated compressed air is equal to about two gallons per hour for each 100 CFM of compressor output.

DRIP LEG DRAIN



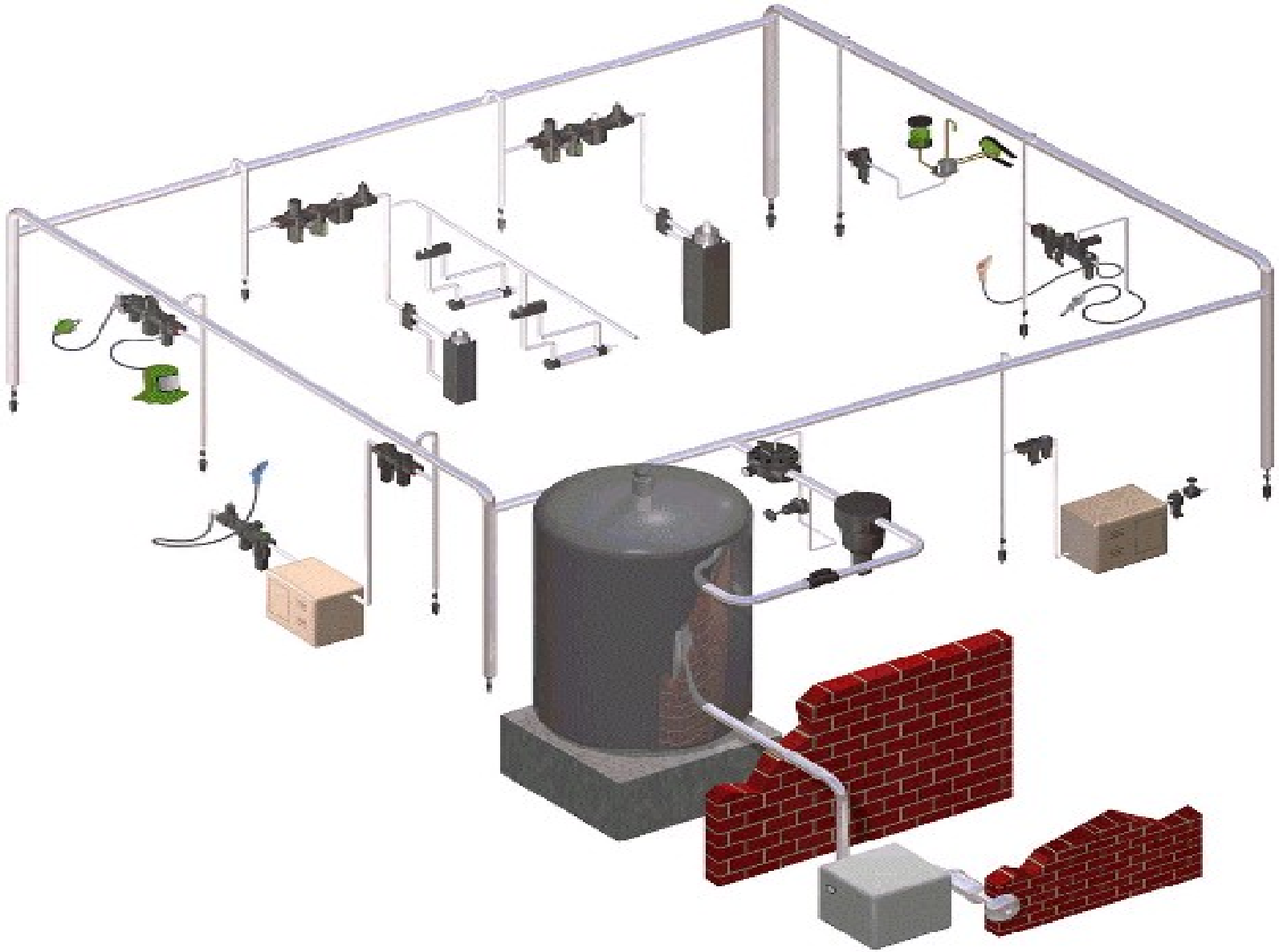
Drip leg drain

- Automatic drain valve for terminating a dead leg
- Water automatically drained when pressure is on, also when shut down
- Fit with an isolating shut off valve for maintenance
- Incorporates a course mesh filter to retain large solid particles
- Built in bleed valve to depressurise the unit prior to maintenance



To eliminate oil, condensate, or cooling water (if the water-cooled aftercooler leaks), a low point drain should be installed in the discharge pipe before the aftercooler. Be sure to connect the aftercooler outlet to the separator inlet when connecting the aftercooler and the moisture separator together. If they are not connected properly, it will result in either poor aftercooling or poor separation.

The main header pipe in the system should be sloped downward in the direction of the compressed air flow. A general rule of thumb is 1" per 10 feet of pipe. The reason for the slope is to direct the condensation to a low point in the compressed air piping system where it can be collected and removed.



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Filter Sizing
Inlet Flow and Inlet/Outlet Piping

The compressed air filter has to be rated for the inlet flow. Inlet flow is generally measured in scfm. Locate the filter at the highest pressure point available that offers an acceptable temperature. Match the inlet and outlet pipe size of the filter assembly to avoid generating excessive pressure drop across the compressed air filter.

High Temperature Particulate Filter

Temperature spikes are common downstream of a heated desiccant dryer. Spikes happen when a regenerated tower comes back online. The heat generated during regeneration is picked up by the compressed air. Often these heat spikes are considerably higher than the maximum operating temperature of a particulate compressed air filter and housing. The particulate filter can catch fire and damage your air system and pneumatic devices.

A high temperature particulate filter protects against this risk of fire. A particulate compressed air filter operates at 100°F (38°C) and has a maximum temperature of 150°F (66°C). A high temperature particulate filter can operate daily at 350°F (177°C) and has a maximum operating temperature of 450°F (232°C). The level of protection with a high temperature particulate filter and housing is significant.

Direct interception is the most common form of retention in both gas and liquid service. Most filters maximize their direct interception with torturous flow paths, which increase the filters retention capability.

Coarser filters intercept larger particles. More densely packed filters intercept smaller particles, but also restrict the airflow, posing the problem of high-pressure drop. Increasing the filter area can compensate for high-pressure drop; but, a balance must be achieved between filter area and practical physical limitations.

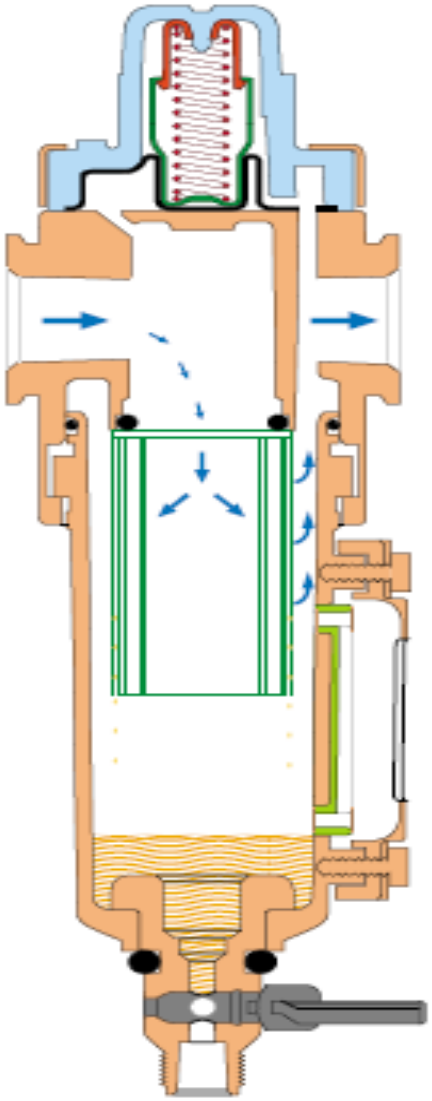
Filtration Theory

Inertial impaction

Particles travelling in a fluid have a mass and velocity. The fluid will follow the path of least resistance. Some particles will impact onto the filter medium and be caught due to their inertia driving them into the filter. This is not a primary mechanism for particle retention. It is more common in gas streams.

OIL

'PURAIRE' COALESCING FILTER



FILTER SERVICE INDICATOR

NORGREN

Other coalescers are designed with pleated elements, providing significantly greater surface area than a non-pleated design, and the inherent reduction in pressure drop and increase in element life.

Still other coalescers are recommended for use in combination with one or more filters, feeding the air-stream to a coarse coalescer prior to a high efficiency coalescer. This type of installation, while inherently higher in pressure drop than the single filter, provides another approach to reducing the inlet contamination to the high efficiency coalescer and results in cleaner air at the outlet.

Oil removal filters typically employ the inertial impaction and diffusion filtration mechanisms to remove oil in the liquid state. These filters are commonly known as coalescers, since they rely on the combination or coalescing of small droplets into larger droplets in the filtration media. These larger droplets then fall away from the element due to gravity. Coalescers are available in a variety of efficiency ratings in order to suit the many applications of compressed air.

Some designs have built-in pre-separation of gross contaminants, such as water and large oil droplets or solid particulates.

Coalescing Filter

A high efficiency coalescer filter removes water and oil aerosols and solid particles to a specified level. Many compressed air coalescers are rated at a liquid removal efficiency of 0.001 ppm by weight and by liquid aerosols down to 0.01µm. A coalescer stops particulate contamination through direct interception. Its main function is to remove water and oil aerosols by coalescing the aerosols into droplets. This happens partially because of torturous path and membrane characteristics and partially due to pressure drop. Coalescers remove both water and oil aerosols from the air stream.

It is important to realize that a coalescer is excellent at removing aerosols and liquids but not vapors. Vapors are organics like hydrocarbons and odors. A vapor filter removes vapors with an adsorbent.

Adsorption

Adsorption is a process that involves the adhering of contaminant molecules to the surface of a solid adsorber. A packed bed of porous materials with high surface-to-volume ratio performs effectively in this capacity. While contaminant molecules lodge in the small pores, cracks, voids and crevices of the adsorbent, air passages remain free, and the effect on pressure drop is negligible.

Adsorption filters are particularly effective in removing oil vapor and are occasionally employed to remove oil aerosols.

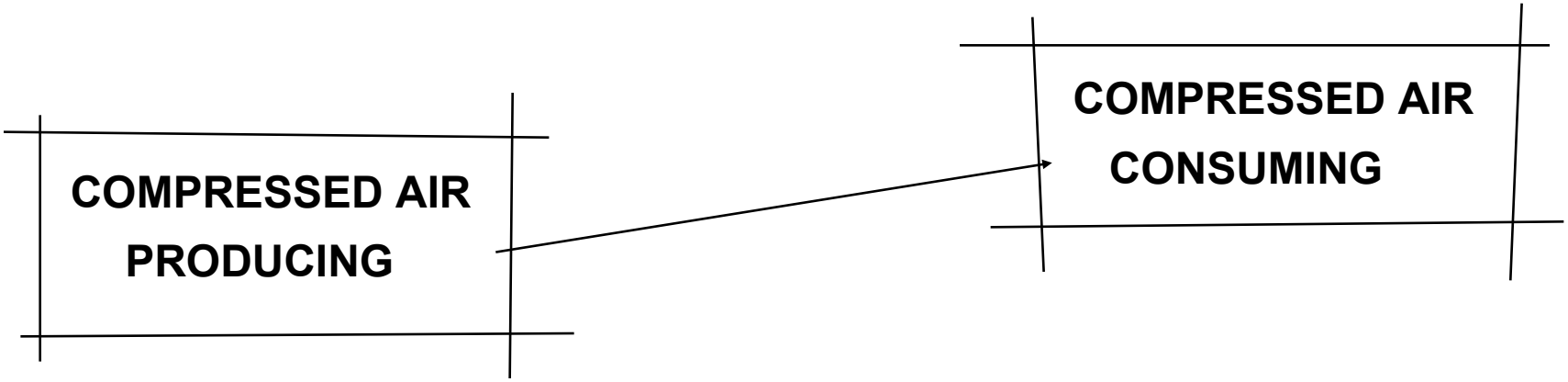
Adsorbers typically employ the adsorption mechanism of filtration to remove hydrocarbon tastes and odors from the air-stream. Most use a special activated carbon to accomplish this.

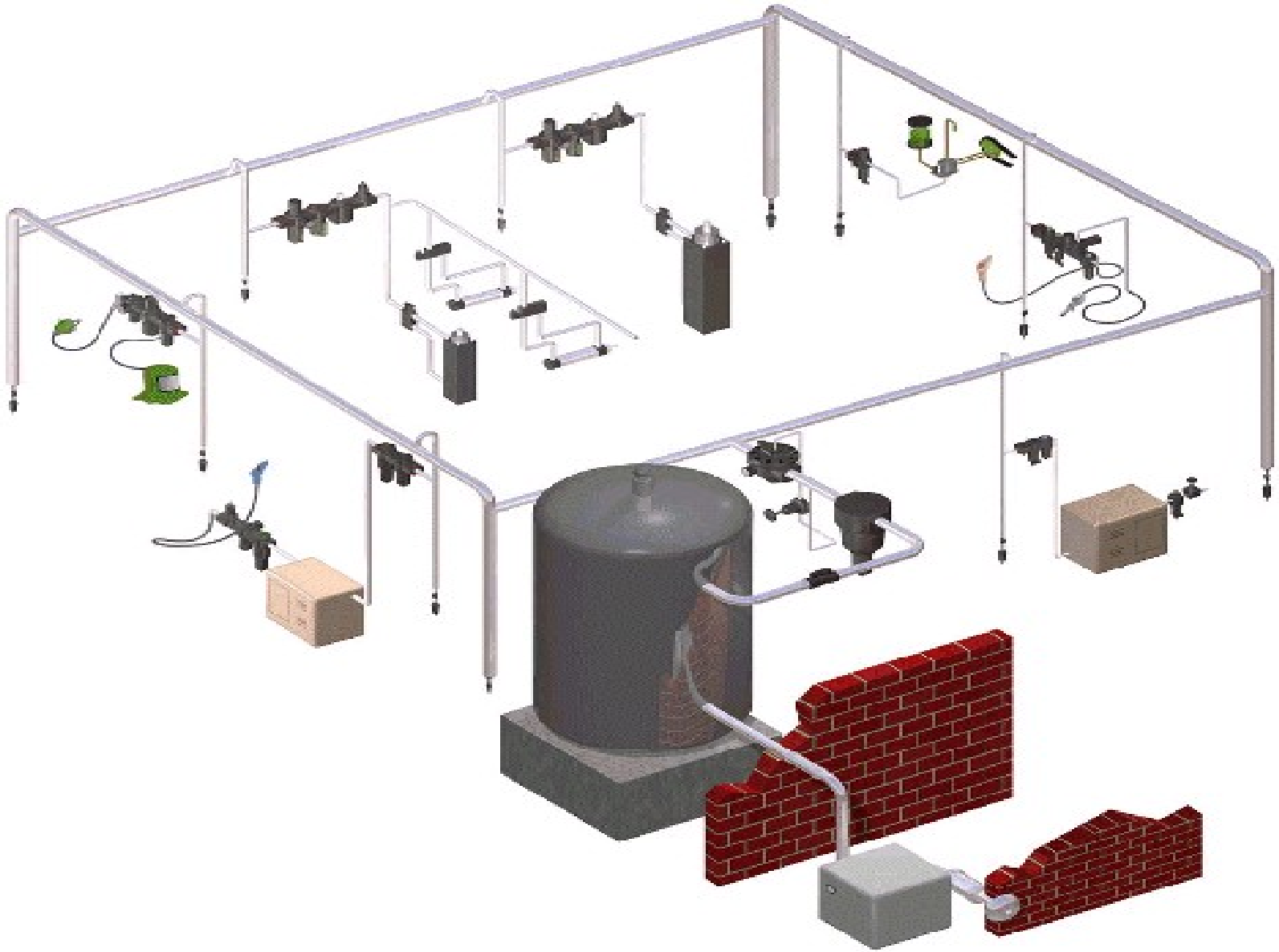
It is never advisable to install a carbon filter without suitable pre-filtration, as carbon filters quickly become ineffective when challenged with liquid oil or water. Although these filters are often used as "final polishing" filters in an air treatment system, they often tend to pass small carbon fines downstream. Therefore, make sure there is a particulate filter either built into the carbon filter or downstream.

Vapor Filter (Charcoal Filter)

A vapor filter removes organics from the air stream. Organics, like tastes and odors need to be removed from breathing air systems. In general, industrial applications of vapor compressed air filters remove hydrocarbons and other organic chemical vapors from the air system. Depending on the airflow, vapor filters need to be replaced every few months because the effectiveness of the activated carbon degrades as it adsorbs.

YOUR COMPRESSED AIR FACILITY





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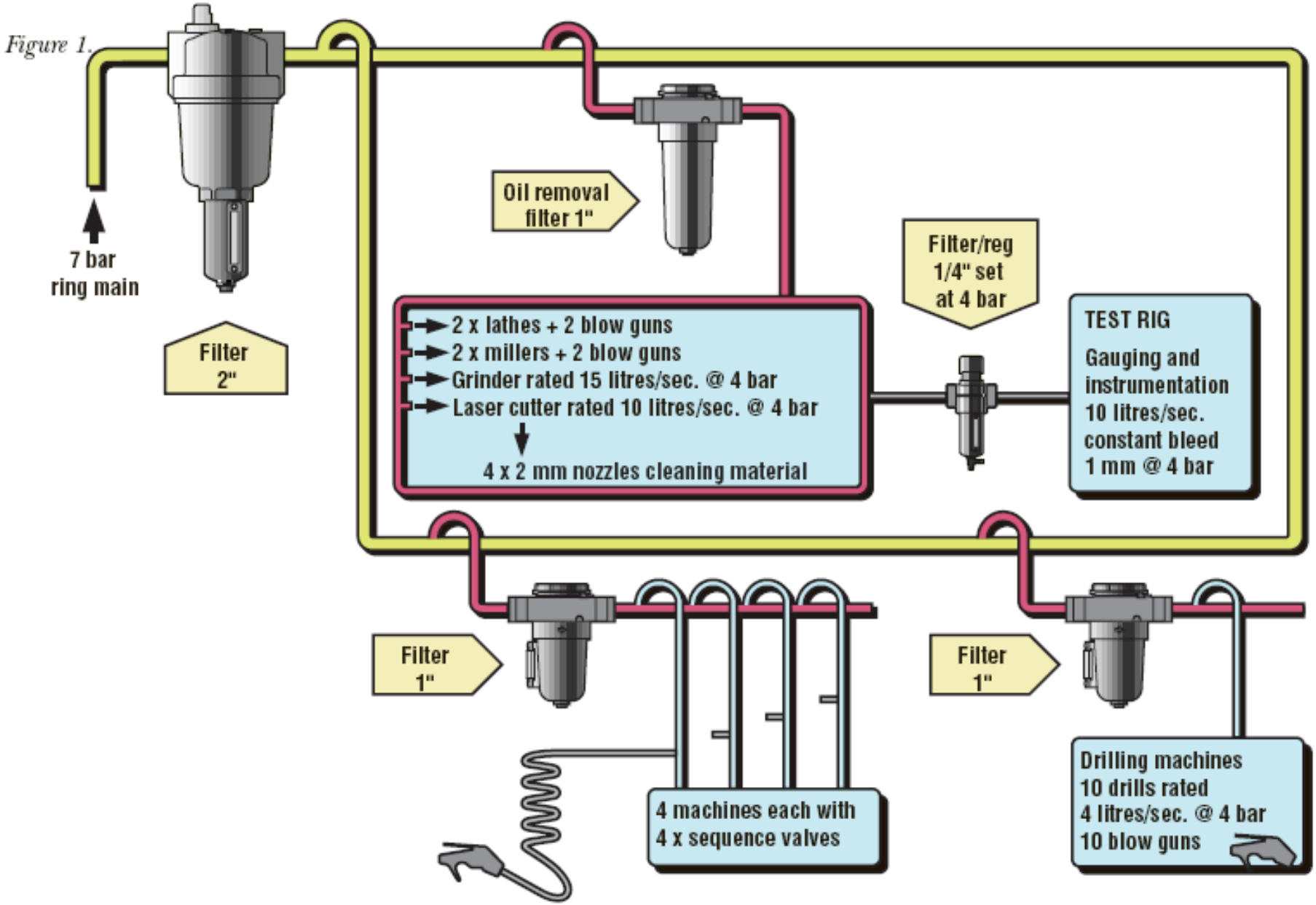
WORKSHOP AREA

KINETIC FLUIDTRONICS INCORPORATED

Figure 1.



Use metal bowl in applications where a plastic bowl might be exposed to substances that are incompatible with polycarbonate.

Polycarbonate plastic bowls can be damaged and possibly burst if exposed to such substances as certain solvents, strong alkalies, compressor oils containing ester-based additives or synthetic oils. Fumes of these substances in contact with the polycarbonate bowl, externally or internally, can also result in damage. Clean with warm water only.

ADJUSTMENT

1. Before applying inlet pressure to filter/regulator, turn adjustment (1 or 7) counterclockwise to remove all force on regulating spring.
2. Apply inlet pressure, then turn adjustment (1 or 7) clockwise to increase and counterclockwise to decrease pressure setting.
3. Always approach the desired pressure from a lower pressure. When reducing from a higher to a lower setting, first reduce to some pressure less than that desired, then bring up to the desired pressure.

Rules of thumb:

There are several rules of thumb regarding compressed air. These rules apply to the design and installation of the system:

All compressors produce heat during the compression process. This heat must be removed from the compressor room for proper operation of the compressor. Be sure to provide sufficient ventilation for all equipment that may be installed in the compressor room. All compressor manufacturers publish allowable operating temperatures.

Leave sufficient space around the compressor to permit routine maintenance. It is also suggested to provide space for the removal of major components during compressor overhauls.

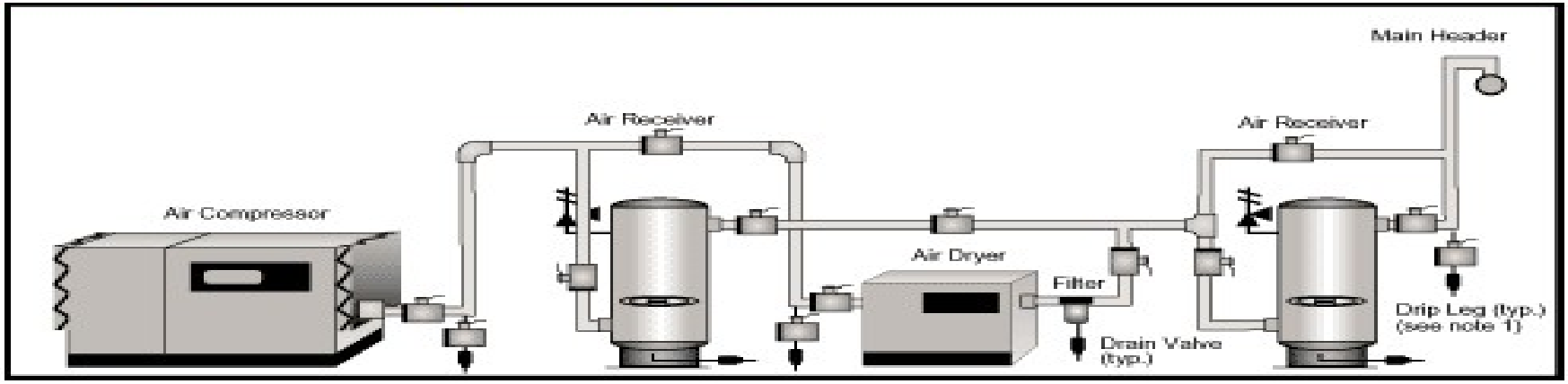
Compressed Air Piping Systems

The purpose of the **compressed air piping system** is to deliver compressed air to the points of usage. The compressed air needs to be delivered with enough volume, appropriate quality, and **pressure** to properly power the components that use the compressed air.
Compressed air is costly to manufacture. A poorly designed compressed air system can increase energy costs, promote equipment failure, reduce production efficiencies, and increase maintenance requirements. It is generally considered true that any additional costs spent improving the compressed air piping system will pay for themselves many times over the **life of the system.**

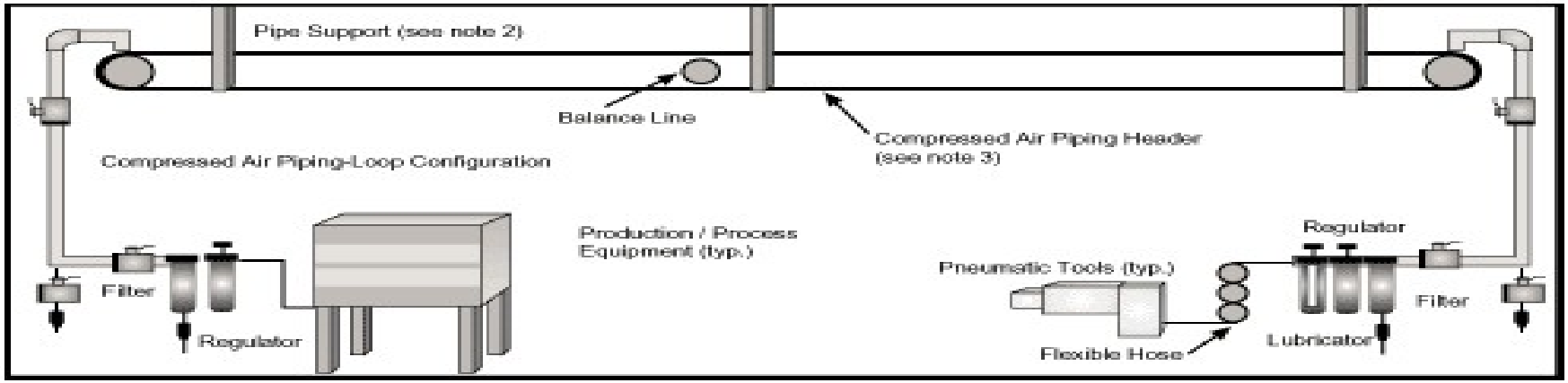
Make sure that the piping following the aftercooler slopes downward into the bottom connection of the air receiver. This helps with the condensate drainage, as well as if the water-cooled aftercooler develops a water leak internally. It would drain toward the receiver and not the compressor.

Another method of controlling the condensation is to take all branch connections from the top of the airline. This eliminates condensation from entering the branch connection and allows the condensation continue to the low points in the system.

Compressed Air System Piping



Compressed Air Equipment Room- Elevation



Production Equipment Room- Elevation

Note: 1) All condensate drained from drain valves and drip legs to be disposed of in accordance with all local, state and federal regulations.
2) All piping to be supported per good engineering practice and pipe system manufacturers recommendations.
3) Compressed air header is to be pitched to provide a means for drainage of liquid water and/or oil that may condense inside the header.
4) Branch line should be taken off of the top of the header to eliminate condensation entering branch line.

Figure P1-1

Pressure Drop

Pressure drop in a compressed air system is a critical factor. Pressure drop is caused by friction of the compressed air flowing against the inside of the pipe and through valves, tees, elbows and other components that make up a complete compressed air piping system. Pressure drop can be affected by pipe size, type of pipes used, the number and type of valves, couplings, and bends in the system. Each header or main should be furnished with outlets as close as possible to the point of application. This avoids significant pressure drops through the hose and allows shorter hose lengths to be used. To avoid carryover of condensed moisture to tools, outlets should be taken from the top of the pipeline. Larger pipe sizes, shorter pipe and hose lengths, smooth wall pipe, long radius swept tees, and long radius elbows all help reduce pressure drop within a compressed air piping system.

In recent years several manufacturers have developed piping systems especially for **compressed air** (fig. P1-2). These compressed air piping systems typically have smooth walls, are lightweight, and reduce the installation costs associated with copper and threaded pipe. Follow the manufacturer's recommendations for installing these systems.

Figure P1-2 Victaulic Pressfit System

Loop Pipe System

The layout of the system can also affect the compressed air system. A very efficient compressed air piping system design is a loop design. The loop design (fig. P1-3) allows airflow in two directions to a point of use. This can cut the overall pipe length to a point in half that reduces pressure drop. It also means that a large volume user of compressed air in a system may not starve users downstream since they can draw air from another direction. In many cases a balance line is also recommended which provides another source of air.

Reducing the velocity of the airflow through the compressed air piping system is another benefit of the loop design. In cases where there is a large volume user an auxiliary receiver can be installed. This reduces the velocity, which reduces the friction against the pipe walls and reduces pressure drop. Receivers should be positioned close to the far ends or at points of infrequent heavy use of long distribution lines. Many peak demands for air are short-lived, and storage capacity near these points helps avoid excessive pressure drop and may allow a smaller compressor to be used.

Piping materials

Common piping materials used in a compressed air system include copper, aluminum, stainless steel and carbon steel. Compressed air piping systems that are 2" or smaller utilize copper, aluminum or stainless steel. Pipe and fitting connections are typically threaded. Piping systems that are 4" or larger utilize carbon or stainless steel with flanged pipe and fittings.

Note: Plastic piping may be used on compressed air systems, however caution must used since many plastic materials are not compatible with all compressor lubricants. Ultraviolet light (sun light) may also reduce the useful service life of some plastic materials. Installation must follow the manufacturer's instructions.

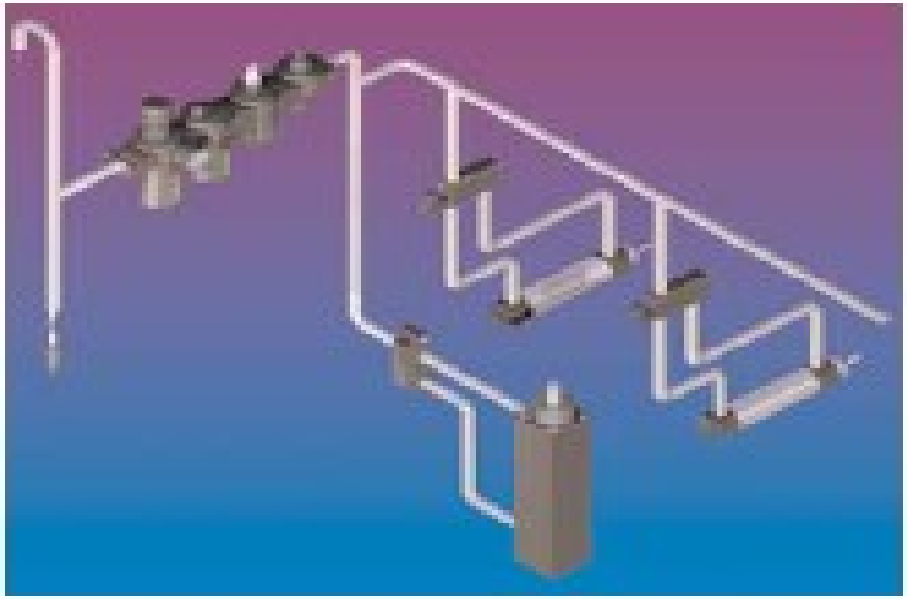
It is always better to oversize the compressed air piping system you choose to install. This reduces pressure drop, which will pay for itself, and it allows for expansion of the system.

Corrosion-resistant piping should be used with any compressed air piping system using oil-free compressors. A non-lubricated system will experience corrosion from the moisture in the warm air, contaminating products and control systems, if this type of piping is not used.

General Pneumatic Circuits:

eg: directional control valves and cylinders, in multi-valve circuits, machine cleaning, air motors and high speed tools.

A Micro-Fog lubricator is required for the several varying flow paths to ensure full lubrication. (Figure 2)



Shut-off valve, filter/reg, Micro-Fog lubricator, soft start/dump, relief valve.

NORGREN

Multiple Simple Applications:

eg: OEM machines.

It is often a case that with fairly simple machines, lubricated air is require for valving and pneumatic circuitry and oil-free air for air bearings. To keep costs low two separate lines are unnecessary and a typical arrangement from one air supply only can be arranged as shown.

Shut-off valve, filter/regulator, oil removal filter, porting block, Micro-Fog lubricator.

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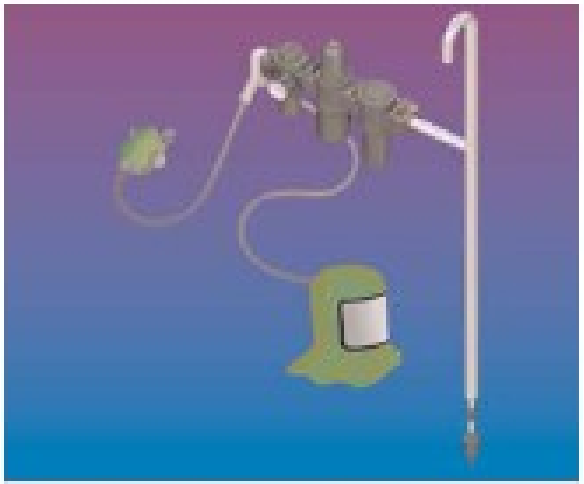
Breathing Air:

eg: face masks and hoods, air agitation.

Figure 4.



Shut-off valve, general purpose filter, Ultraire filter, regulator.

The typical application assumes that air intakes are of a reasonable quality with no CO or CO^2 contamination. It may in some instances be a consideration to remove water vapor. (Figure 4)

Figure 16.
OIL REMOVAL FILTER WITH GENERAL PURPOSE PRE-FILTER

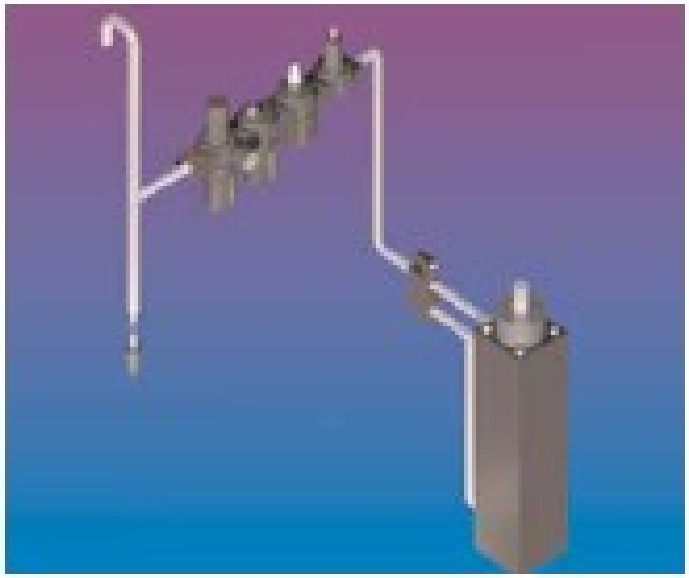
NORGREN

Heavy Duty Lubrication:

eg: large slow moving cylinders.

In such applications large amounts of lubricant are required for effective lubrication. Again a soft start/dump valve is shown but is dependent upon the application. (Figure 6).

Figure 6.



Shut-off valve, filter/reg, Oil-Fog lubricator, soft start/dump valve, relief valve.

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KINETIC FLUIDTRONICS INCORPORATED

Recommended oils for use with Norgren lubricators heavy duty tool lubricants (ISO 3448 viscosity grades 32 to 68) for standard air tools and cylinders.

Manufacturer	Product viscosity number	ISO 3448
British Petroleum	Energal HLP32	32
Castrol	Hyspin AWS32	32
Century	PWLA	32
Elf	Elfona 32	32
Esso	Nuto H32	32
Gulf	Harmony 32	32
Mobil	SHC 524	32
Shell	Tellus 32	32
Texaco	Rando 32	32
Shell	Tellus 37	37
Gulf	Hydrasil 46	46
British Petroleum	Energal HLP46	46
Shell	Tellus 46	46
Texaco	Regal Oil R & 046	46
Rocol	MO-10	46
British Petroleum	Energal HLP68	68

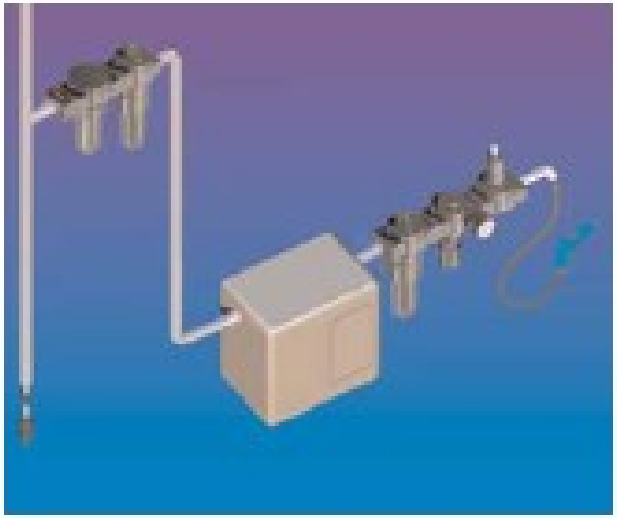
Light duty tool lubricants (ISO 3448 viscosity grades 10 to 22) for small air tools

Manufacturer	Product viscosity number	ISO 3448
British Petroleum	Energal HLP10	10
Castrol	Hyspin AWS10	10
Shell	Tellus R10	10
Total	Azolla ZS10	10
Century	P198	15
Duckhaams	Zeroflo 15	15
Elf	Elfolna	15
Esso	Nuto H15	15
Mobil	Gargoyle Artic Oil Light	15
Rocol	MO-4	15
Shell	Tellus 22	22

Oil-Free Applications:

eg paint spraying, foodstuffs, film processing, powders.

These applications need to be free from any water deposits in the downstream system. For many installations this will require air drying. The drying medium (for desiccant or deliquescent dryers) will need protecting from oil to allow it to work efficiently and the down-stream system will also need protection from accidental migration of the material into it. A



Shut-off valve, general purpose filter, oil removal filter, drier, oil removal filter, regulator, relief valve.

MEMBRANE DRIERS

W07M, W72M, W74M

G¼, G½

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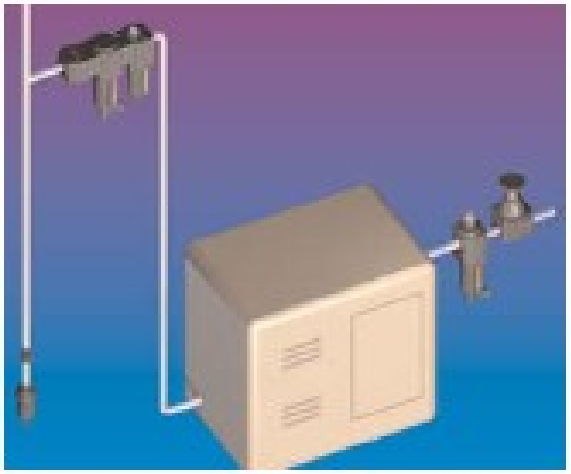
Critical Pressure Control (Instrumentation):

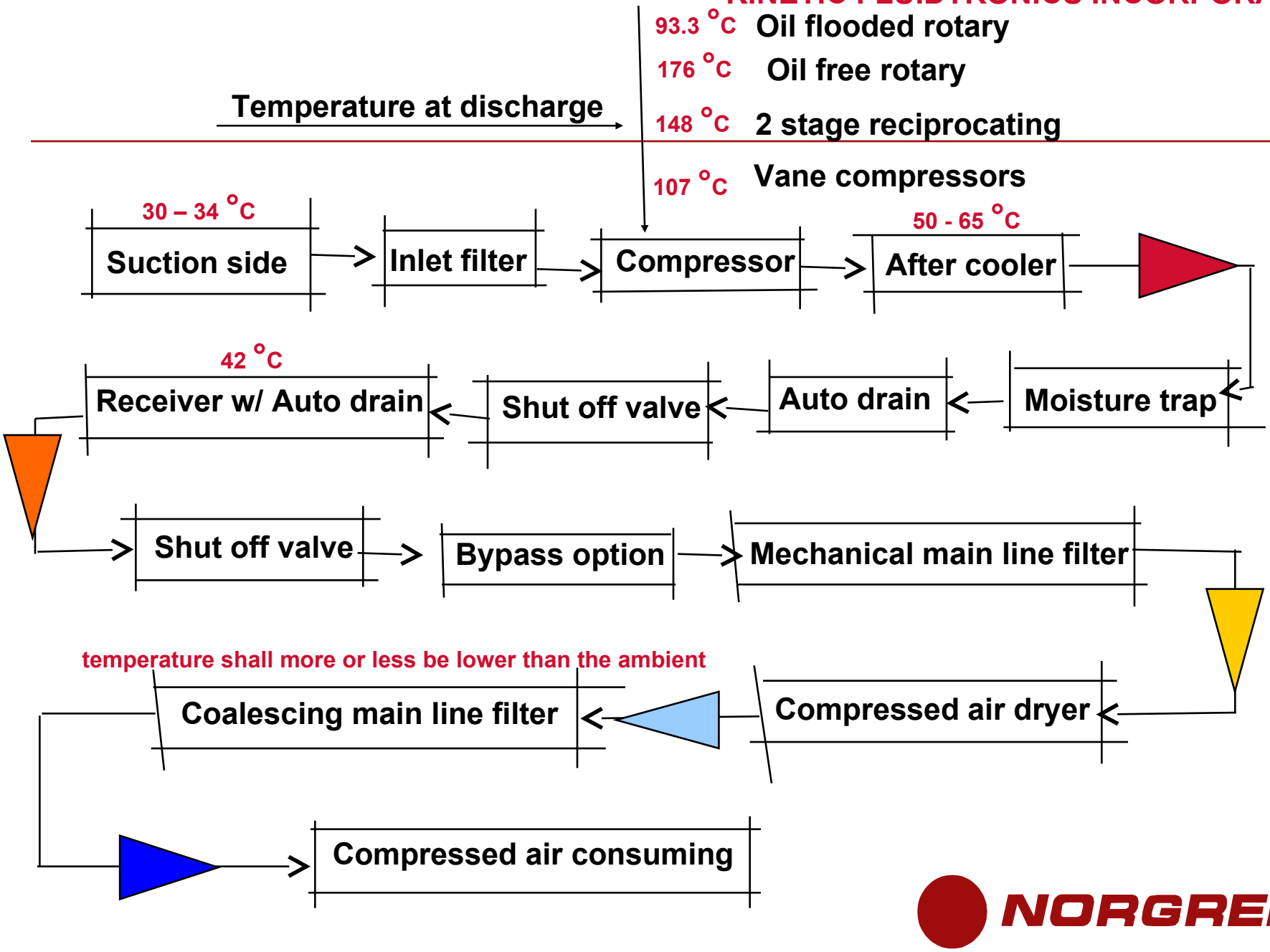
eg: precision regulation, fluidic systems, air gauging, process control.

A typical arrangement is shown, where oil aerosols which can prevent fast response of downstream devices, need to be removed. Dependant upon air quality drying may not be required. (Figure 7)

Figure 7.



Shut-off valve, general purpose filter, oil removal filter, drier, oil removal filter, precision regulator.


Temperature at discharge
93.3 °C Oil flooded rotary
176 °C Oil free rotary
148 °C 2 stage reciprocating
107 °C Vane compressors
30 – 34 °C
Suction side
Inlet filter
Compressor
50 - 65 °C
After cooler
42 °C
Receiver w/ Auto drain
Shut off valve
Auto drain
Moisture trap
Shut off valve
Bypass option
Mechanical main line filter
temperature shall more or less be lower than the ambient
Coalescing main line filter
Compressed air dryer
Compressed air consuming

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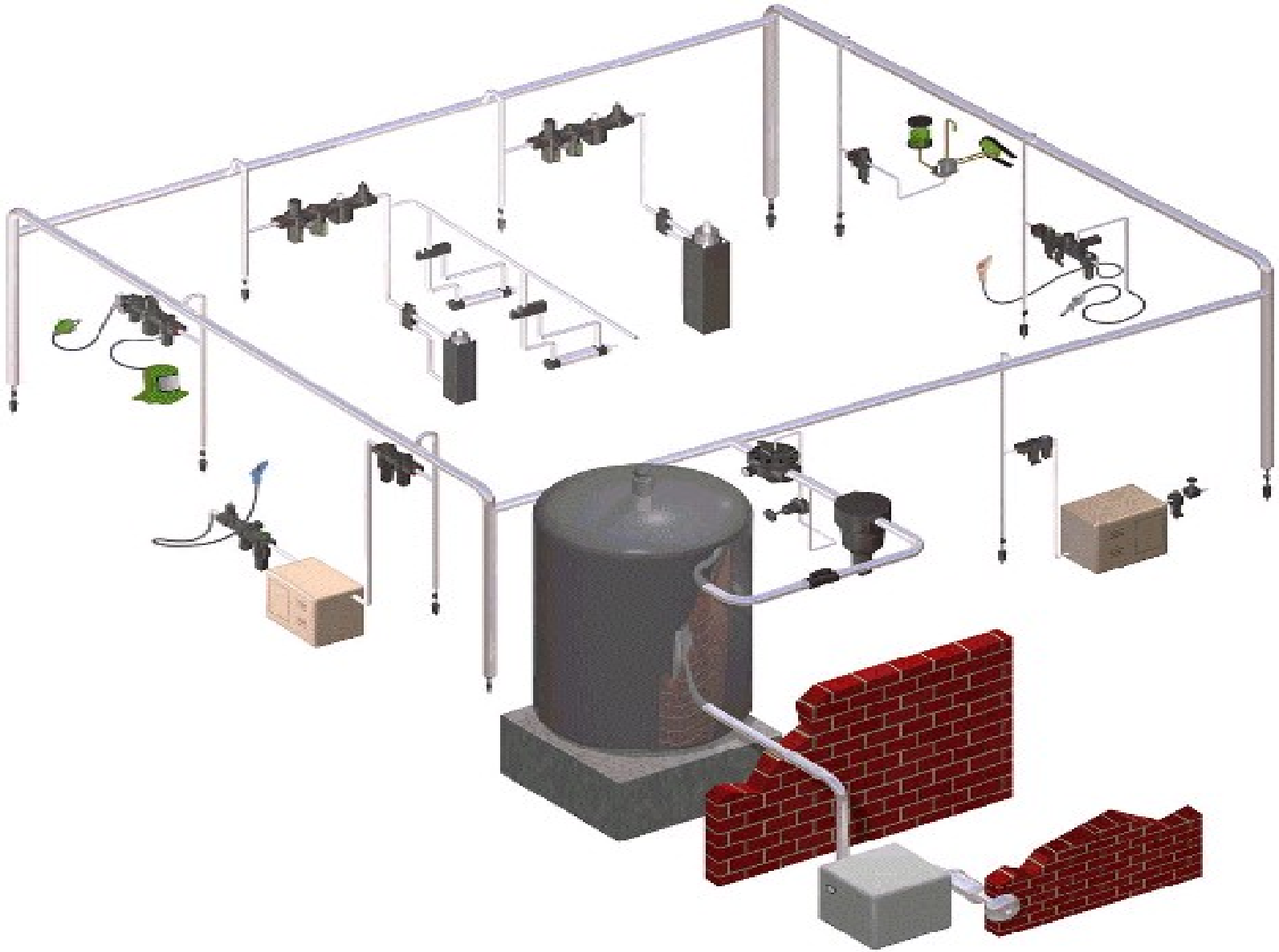

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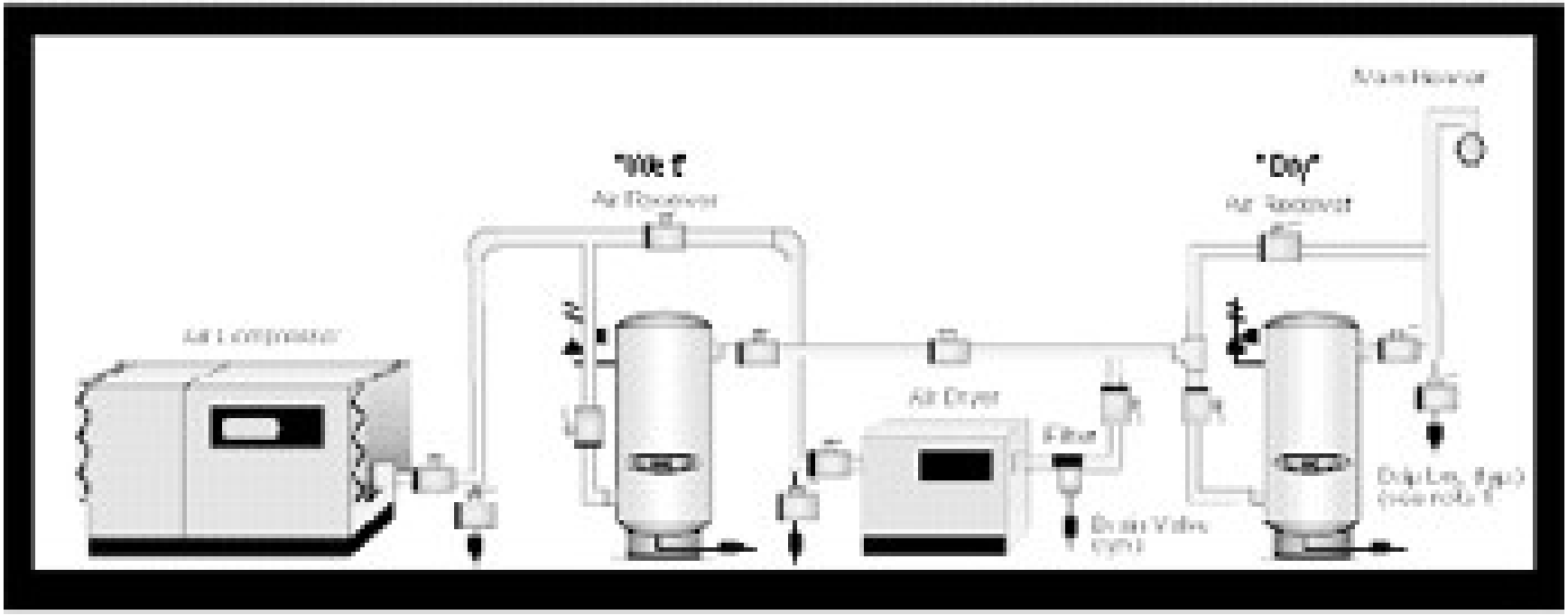
Wet vs. dry receiver:
There are wet air receivers and dry air receivers. (fig. AR1-3)

Wet Receivers: Wet receivers provide additional storage capacity and reduce moisture. The large surface area of the air receiver acts as a free cooler, which is what removes the moisture. Because the moisture is being reduced at this point in the system, the load on filters and dryers will be reduced.



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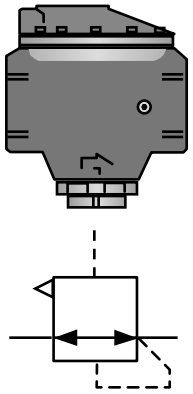
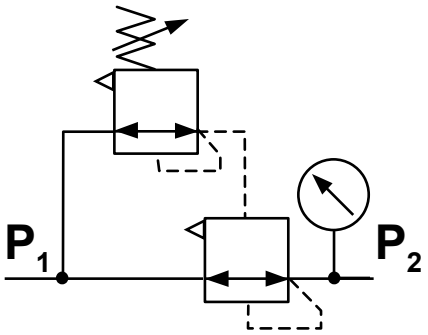
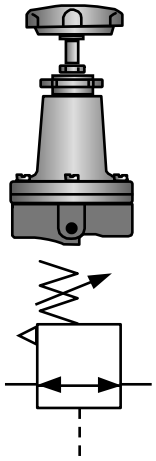
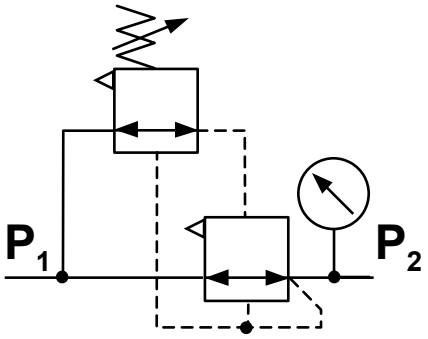
Pilot regulators

- Large pressure regulators generate high forces, unsuitable for direct manual operation
- Often mounted in remote locations difficult to reach
- A piloting regulator is easy to operate and sends a signal to adjust the remote pilot regulator
- Independent or single loop feedback dependant on piloting regulator type, internal or external



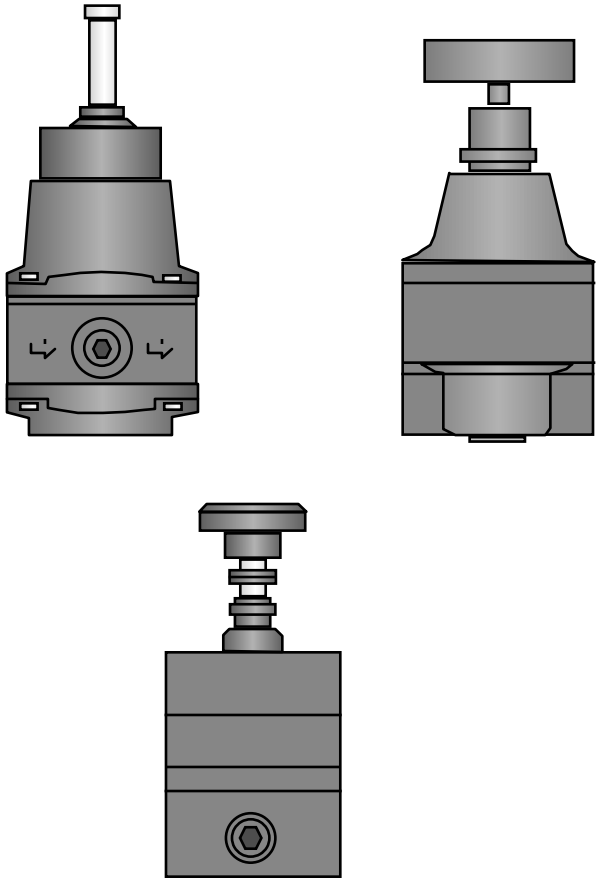






Precision regulators

- Types R38, 11-818 and R27
- For precisely set and accurately held pressure
- Suitable for process control, air gauging and instrumentation
- Selection of pressure ranges e.g. 0.02 -0.5 bar, 0.06-4 bar, 0.16-7bar etc.
- Manual, mechanical and pilot operation



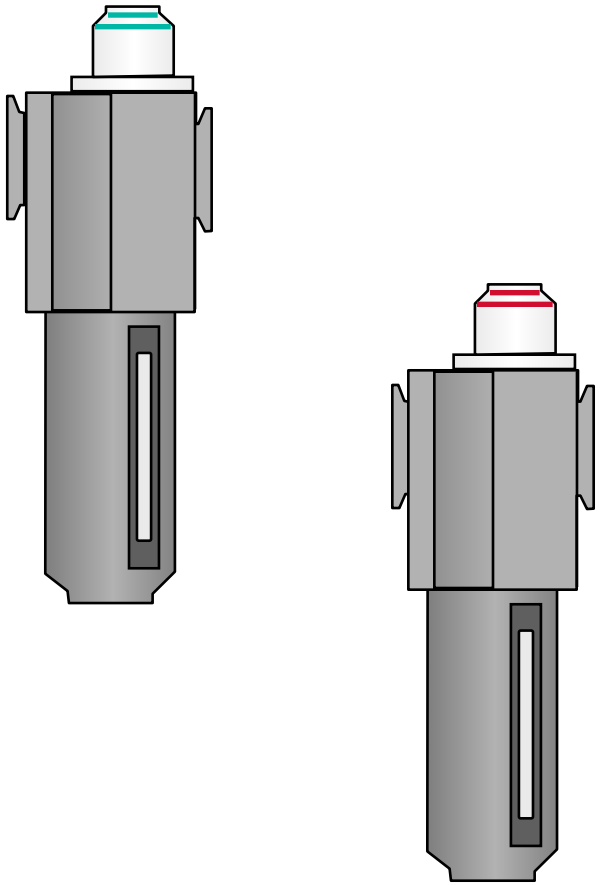
Lubrication

- For efficient running of pneumatic equipment and long life of seals and wearing surfaces, correct lubrication is essential
- Where non-lube equipment is used it has been pre-lubricated on assembly and will last for the normal life expectancy of that equipment without further lubrication. It will not be detrimental however to include this equipment on lubricated air supplies and is likely to result in an extension of the normal life of the equipment
- For the best results light lubrication is applied continuously from an air line lubricator. This is particularly relevant in adverse applications where there may be high speed and high temperature running or where the condition of the compressed air has been poor

Lubrication

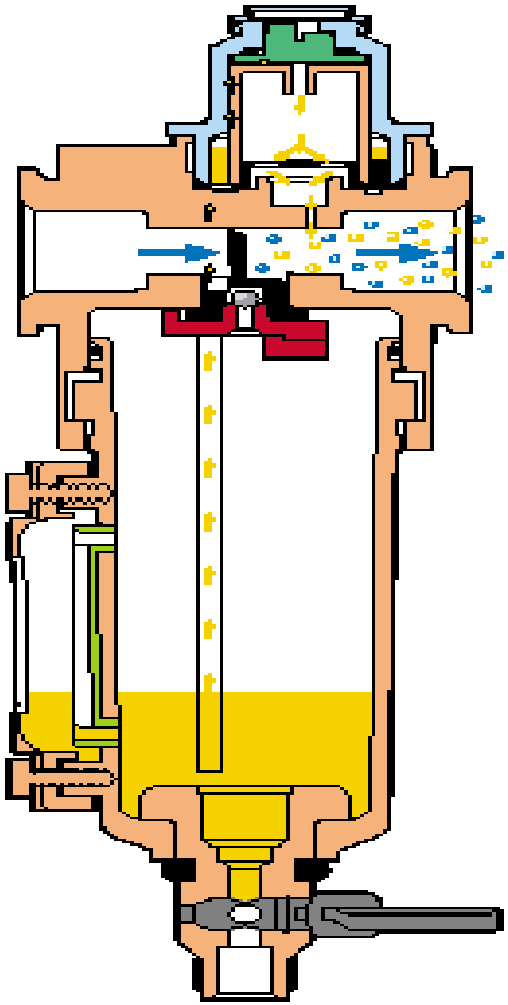
- Valves, actuators and accessories in a typical application can operate at different rates and frequencies and require lubrication rates to match. The airline lubricator provides a very convenient method of satisfying this demand
- In a lubricator, oil drips are atomised and the tiny oil particles form a very fine mist in the air supplying the application
- The amount of oil delivered is automatically adjusted as the air flow changes. The result is constant density lubrication. For any setting the oil particles per cubic meter of air are the same regardless of the flow rate

Lubricators

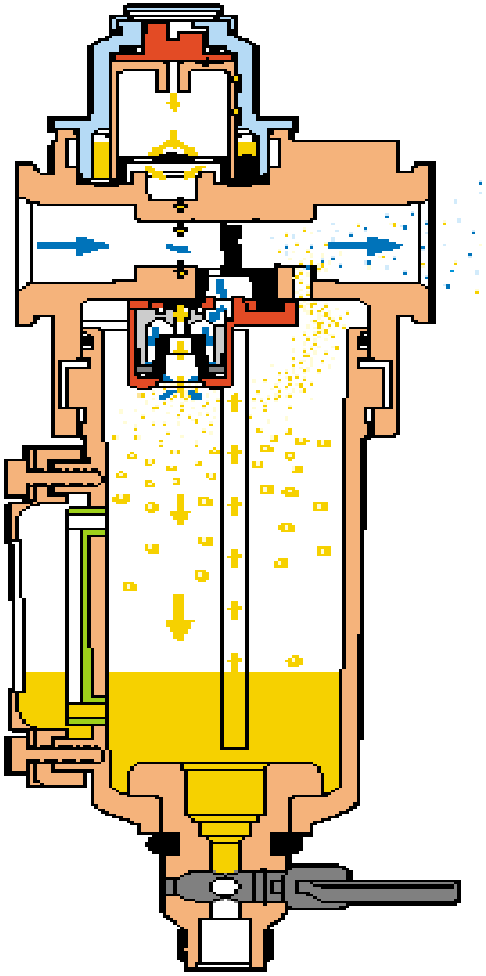


- There are two main types of lubricator
- One is the conventional high delivery Oil Fog series (coded green)
- The other is the unique and more widely used Micro Fog range (coded red)
- Both types are easily adjusted to pre-set the lubrication density

Oil-Fog Lubricator



Micro-Fog Lubricator



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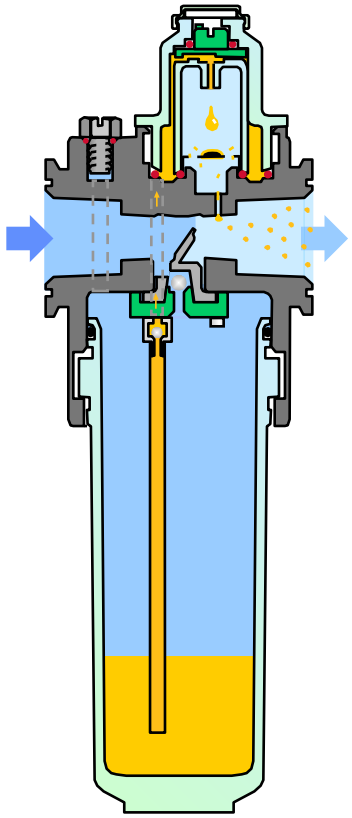
Oil fog lubricators

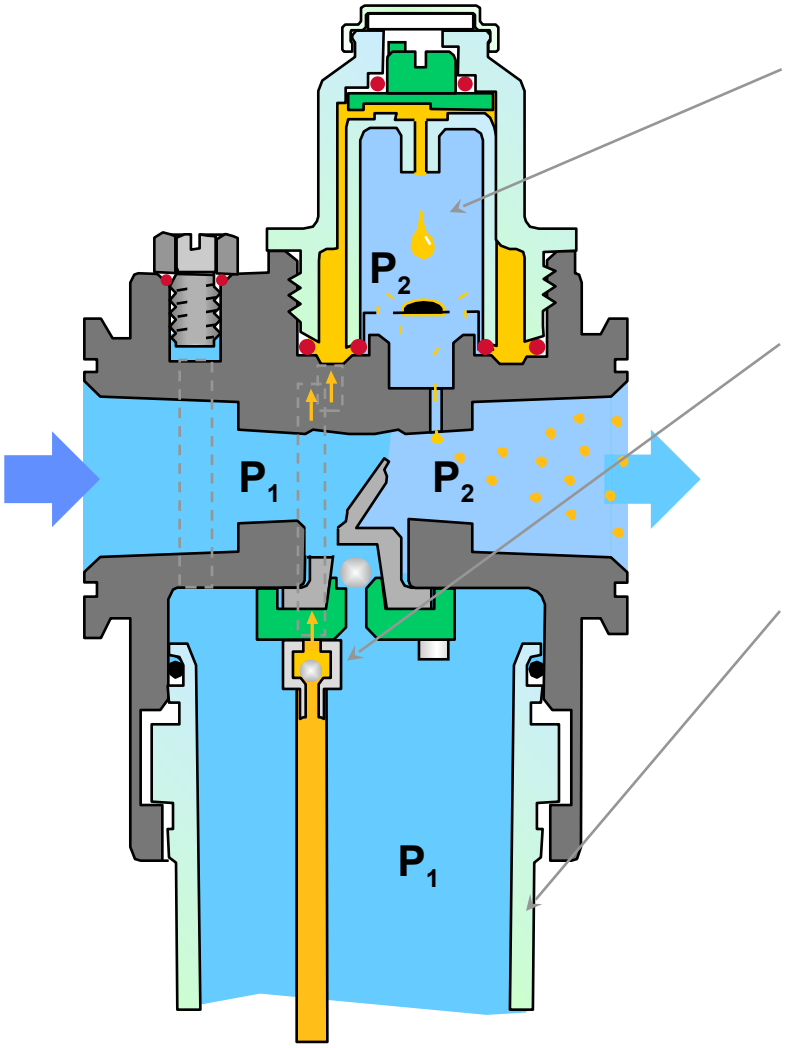
- Oil fog lubricators are often referred to as high delivery units and can be identified by the green drip rate control
- All of the oil drips seen through the sight dome enter the air stream and are atomised
- The size range of the oil particles produced are ideally suited to lubricating single items of equipment on medium to short runs of pipe
- The oil particles are carried along with the air flow, and gradually "wet out" to provide adequate lubrication for applications such as nut runners, screwdrivers and other equipment requiring heavier lubrication

Oil fog lubricator



- For lubricating over short distances where wet-out is required early
- Suited for; air tools, air motors, single large cylinders etc.
- Oil drips are broken up in the main air stream and all particle sizes carried in the air
- Drip rate is adjustable

Oil fog lubricator



- Oil drips visible through the sight dome pushed by the pressure difference between P_1 and P_2
- Syphon tube with check valve to prevent oil drain back when there is no flow taking place
- Transparent polycarbonate bowl to inspect oil level
- Alternative metal bowl with sight glass

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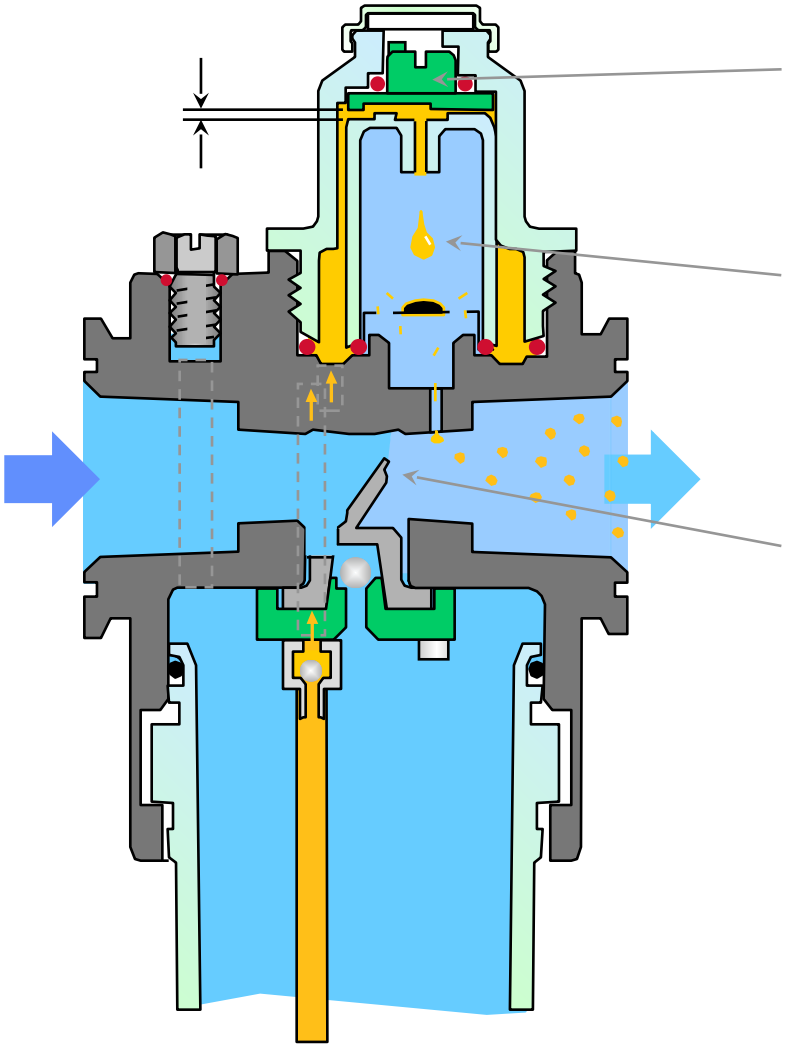
Oil-Fog Lubricators - Determine the average rate of flow thru the lubricator. Turn slotted green rotator in sight feed dome (4) to obtain one drop per minute for each 5 dm^3/s (10 scfm). For example, if the average flow is 19 dm^3/s (40 scfm), set the drip rate at 4 drops per minute. Turn rotator counterclockwise to increase and clockwise to decrease the drip rate. Total travel of rotator is 320°.

Drip Rate Chart for Micro-Fog Lubricators

Flow - dm^3/s (scfm)	Drops per Minute
0,9 to 2,4 (2 to 5)	7
2,4 to 14,2 (5 to 30)	8
14,2 to 18,9 (30 to 40)	9

Oil fog lubricator



- Turn the green control to adjust the oil flow restriction
- Observe the drip rate and set to 2 drips/min at 10 dm^3/s. Change from this according to results
- Flexible flow sensor, progressively bends flat as the flow increases. This controls the local pressure drop to draw oil drips in proportion to air flow

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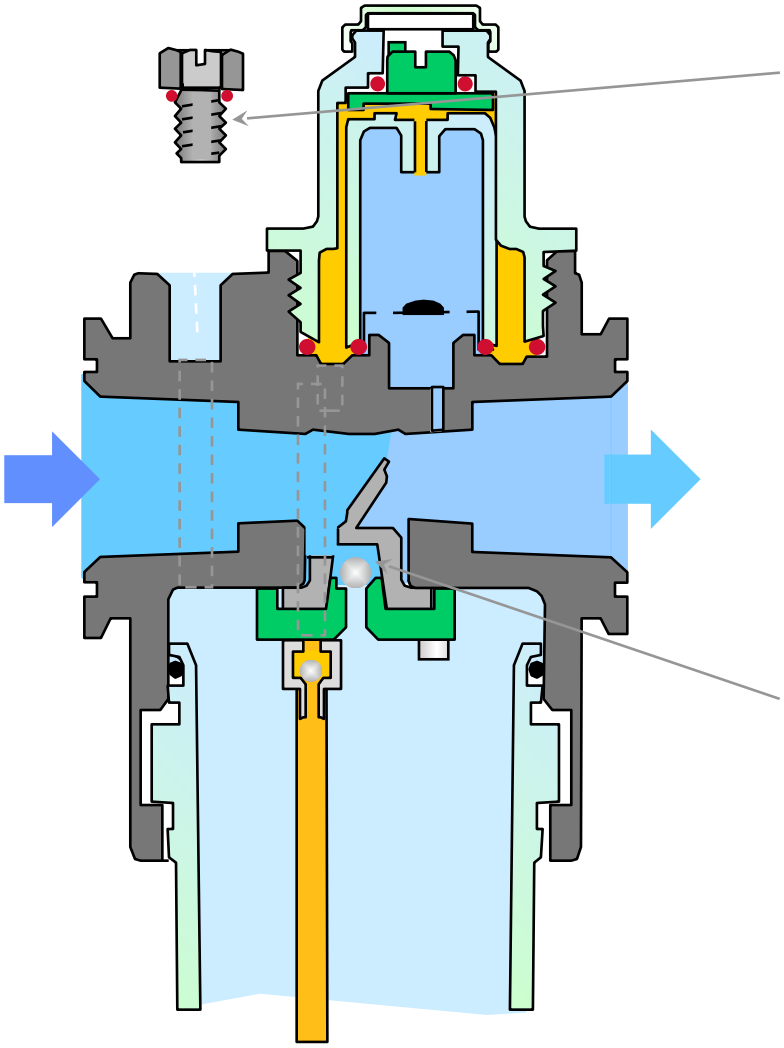
Fill under pressure (oil fog)



- Filler plug with flats to bleed the bowl pressure
- Crack open and wait for pressure to drop then remove the plug
- Remove bowl with simple bayonet action, fill and replace securely
- Replace plug and tighten
- Check valve with small by-pass notch. Flow too low to pressurise bowl when plug removed

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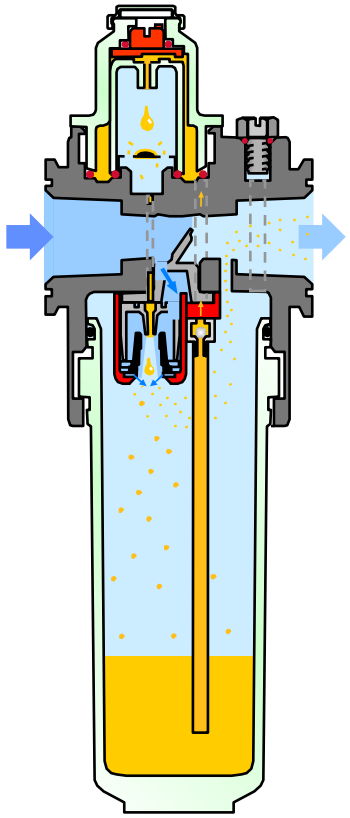
Micro-fog lubricators

- Micro-Fog lubricators are the most widely applied type and can be identified by the red drip rate control
- The oil drips seen through the sight dome in this unit are atomised in the bowl, but only a small percentage of the particles produced actually enter the air stream
- Those that do, make up about 10% of the drip rate and are the very smallest ones, so fine they can be likened to thin smoke. The drip rate is 10 times that of the oil fog units for the same oil delivered. Setting the drip rate is 10 times quicker too as there is less time to wait between drips
- Wetting out of these oil particles occur gradually. This allows them to be carried the long distances associated with the maze of pipework, tight turns and fittings that form part of the typical industrial pneumatic system

Micro-fog lubricator



- For lubricating over long distances where particles must reach the furthest parts of intricate systems
- Suited to; control circuitry, multiple valve / actuator systems
- Oil drips are atomised in the bowl
- Only the finest 10% of oil particles leave the bowl
- Stay in suspension longer